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# MONTHLY NOTICES

OF THE

# ROYAL ASTRONOMICAL SOCIETY.

VOL. LIV. NO. 1. NOVEMBER 1893.

(Nos. 1-3, 5-7, 9)

Fellows of the Society are informed that post-cards containing the titles of papers to be read at the evening meetings will be sent to those who shall express their wish to receive them. Fellows desiring to receive the post-cards are requested to send their names to the Assistant-Secretary, Mr. W. H. Wesley, Burlington House, London, W.

In order to enable the Secretaries to prepare complete lists in time for the issue of the post-cards, authors are particularly requested to send in their papers not later than the Tuesday preceding the day of meeting.

# MONTHLY NOTICES

OF THE

# ROYAL ASTRONOMICAL SOCIETY.

VOL. LIV. NOVEMBER 10, 1893. No. 1

Captain W. DE W. ABNEY, C.B., R.E., D.C.L., F.R.S., President, in the Chair.

William Murray Dobie, M.D., J.P., Northgate House, Chester;
Roland Pillans, Geodetic Survey, Royal Observatory, Cape of Good Hope;
Dr. Charles Lane Poor, Astronomer in the Johns Hopkins University, Baltimore, Md., U.S.A.; and
Thomas Jefferson Jackson See, Ph.D., University, Chicago, U.S.A.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

John Harrison Buckley, 70 Tower Street, Leicester (proposed by T. D. Brewin);
William Briggs, B.A., LL.B., F.C.S., Burlington House, Cambridge (proposed by Robert Bryant);
J. Evershed, Junr., Chemical Manufacturer, Kenley, Surrey (proposed by A. Cowper Ranyard);
Joshua Jukes, 43 High Street, Smethwick, near Birmingham (proposed by Arthur Mee);
Henry Alfred Lenehan, Astronomical Assistant, Government Observatory, Sydney, N.S. Wales (proposed by H. C. Russell);

Armin Otto Leuschner, A.B., Assistant Professor of Astronomy in the University of California (proposed by J. E. Keeler);

Henry MacEwen, Engineer, 5 Cathkin Terrace, Mount Florida, Glasgow (proposed by L. Becker);

The Rev. David Powell Richards, B.A., Chaplain and Naval Instructor to H.M.S. *Canada*, Bermuda;

Richard Pickering Sellors, B.A., Astronomical Observer, Government Observatory, Sydney, N.S. Wales (proposed by H. C. Russell),

Dr. Max Wolf, Professor of Astronomy in the University of Heidelberg, The Observatory, Heidelberg (proposed by A. Cowper Ranyard).

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Two hundred and twelve presents were announced as having been received since the last meeting, including, amongst others: Professor O. J. Lodge, Aberration Problems; F. C. Penrose, Results of Examination of Orientation of Greek Temples; S. C. Chandler, Second Catalogue of Variable Stars; O. A. L. Pihl, On Occulting Micrometers, presented by the Authors; Barlow and Bryan, Elementary Mathematical Astronomy, second edition, presented by the Publishers; E. M. Clerke, The Planet *Venus*; E. W. Buller, Semi-Azimuths; A. Mukhopadhyay, The Geometry of Conics, presented by the Authors; J. E. Gore, An Astronomical Glossary, presented by the Publishers; M. Lœwy, Sur la Détermination des Constantes des Clichés Photographiques du Ciel; A. M. Clerke, History of Astronomy during the 19th Century; P. Henry, Mesures et Réductions des Clichés Photographiques du Catalogue de la Carte du Ciel, presented by the Authors; Leander McCormick Observatory, Observations of Southern Nebulæ; Harvard Observatory, Annals, vol. xix. pt. 2 (On the Zodiacal Light, &c.); Berlin Observatory, Zonenbeobachtungen der Sterne zwischen $+20°$ und $+25°$; Kiel Observatory, Catalog der farbigen Sterne; Madras Observatory, Results of Meridian Observations, 1877–79; Cordoba Observatory, Durchmusterung, Catalogue, pt. 1, presented by the Observatories; Observations of the Transit of *Venus*, 1874, made in N.S.Wales, presented by H. C. Russell; Opere di Galileo, edizione nationale, vol. iii. (Sidereus Nuncius), presented by the Italian Government; Œuvres complètes de Laplace, tome ix., presented by the French Academy; T. G. Rylands, The Geography of Ptolemy, presented by the Author; Series of re-touched enlargements from Lick Observatory negatives of the Moon, presented by Professor Weinek; A drawing of *Saturn*, presented by B. E. Cammell; J. M. Schaeberle, Series of transparencies from negatives of the Solar Eclipse of 1893 April, presented by the Lick Observatory; A new form of planisphere, presented by A. H. Molesworth.

*Observations of the Moon made at the Radcliffe Observatory, Oxford, during the Year 1892; and a Comparison of the Results with the Tabular Places from Hansen's Lunar Tables.*

By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

The present paper contains the observations of the Right Ascensions and North Polar Distances of the Moon, made at the Radcliffe Observatory during the year 1892. These results are here compared with those deduced from Hansen's Lunar Tables on two suppositions—

(1) That the mean times found in the usual way, from the sidereal times at mean noon given in the *Nautical Almanac*, were not altered in scale, or affected with any different systematic errors of determination, by the adoption, in 1864, of a different ratio of the Julian year of $365\frac{1}{4}$ "mean solar days" to the mean tropical year.

(2) That the "mean solar times" which accurately correspond to given "local sidereal times" before and after 1864 are necessarily different from the adoption and use of a "Julian year" and "mean solar day" which are different fractional parts of the mean tropical year, and therefore are different intervals of absolute time.

If these differences are real, and are neglected by astronomers in referring the tabular positions of the Sun, Moon, &c., to the meridians for comparison with the local sidereal times at transit, the effects of the errors made will necessarily be thrown upon the theoretical expressions.

The differences of the errors thus made in practice, according to my views, before and after 1864, are given in Table III.

The periodical errors of Hansen's Tables, after correction, shown by the observations during the year 1892, are not larger than those which will be found to exist during the years 1847 to 1863.

The mean annual errors of Hansen's Tables show small but systematic periodical changes from 1847 to 1863, but since 1864 the errors in longitude have progressively increased until they amount in 1892 to $+19''{\cdot}7$. It will be seen that after the corrections, which I have indicated as necessary for a comparison of the changes of the errors of Hansen's Tables before and after 1864, have been applied, the *per saltum* change in 1864 is no longer shown. The mean annual error in longitude, 1847–63, is $-1''{\cdot}85$; the mean annual error in longitude, 1864–92, is $-1''{\cdot}56$; and the mean annual error in longitnde for the whole period, 1847–92, is $-1''{\cdot}67$.

For facilities for an accurate comparison between Hansen's Lunar Tables and Observations I am again indebted to the places published in the *Connaissance des Temps*.

TABLE I.

*Radcliffe Observations of the Moon*, 1892.

*R.A.'s and N.P.D.'s of the Centre of the Moon*, 1892; *compared with Hansen's Tabular Places*, **Uncorrected** *and* **Corrected** *for the change in the Unit of Mean Time introduced in the year* 1864.

| Day, 1892. | Correction to be subtracted from M.T. for Change of Sidereal Time at Mean Noon since 1864. | Observer. | Limb observed in R.A. | Observed R.A. | R.A. from Hansen's Tables for Uncorrected Mean Times. | Hansen *minus* Observed. **Uncorrected.** | Correction due to the Change in the Unit of Mean Time. | Hansen *minus* Observed. **Corrected.** | Limb observed in N.P.D. | Observed N.P.D. | N.P.D. from Hansen's Tables for Uncorrected Mean Times. | Hansen *minus* Observed. **Uncorrected.** | Correction due to the Change in the Unit of Mean Time. | Hansen *minus* Observed. **Corrected.** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | s | | | h m s | s | s | s | s | | ° ′ ″ | ″ | ″ | ″ | ″ |
| Jan. 6 | 41·51 | F.B. | I. | 0 49 19·57 | 20·93 | +1·36 | −1·46 | −0·10 | S. | 88 30 23·16 | 13·35 | − 9·81 | +10·98 | +1·17 |
| 7 | 41·52 | W. | I. | 1 41 51·40 | 52·80 | +1·40 | −1·48 | −0·08 | S. | 82 3 10·94 | 1·25 | − 9·69 | +10·52 | +0·83 |
| 11 | 41·53 | F.B. | I. | 5 32 49·34 | 50·84 | +1·50 | −1·73 | −0·23 | N. | 64 12 47·86 | 45·31 | − 2·55 | + 2·93 | +0·38 |
| 13 | 41·54 | R. | I. & II. | 7 36 43·36 | 44·66 | +1·30 | −1·67 | −0·37 | N. | 64 5 24·81 | 26·40 | + 1·59 | − 2·64 | −1·05 |
| 15 | 41·55 | R. | II. | 9 29 56·92 | 58·07 | +1·15 | −1·47 | −0·32 | S. | 69 53 54·79 | 60·20 | + 5·41 | − 6·71 | −1·30 |
| Feb. 3 | 41·62 | F.B. | I. | 1 25 6·62 | 7·90 | +1·28 | −1·50 | −0·22 | S. | 83 47 26·14 | 16·19 | − 9·95 | +10·95 | +1·00 |
| 8 | 41·64 | R. | I. | 6 13 52·97 | 54·34 | +1·37 | −1·71 | −0·34 | N. | 63 17 14·81 | 13·80 | − 1·01 | + 0·96 | −0·05 |
| 11 | 41·66 | F.B. | I. | 9 8 54·22 | 55·61 | +1·39 | −1·50 | −0·11 | N. | 68 25 1·66 | 6·50 | + 4·84 | − 6·13 | −1·29 |
| 16 | 41·68 | F.B. | II. | 13 2 50·93 | 52·13 | +1·20 | −1·23 | −0·03 | S. | 93 35 54·13 | 60·35 | + 6·22 | − 9·24 | −3·02 |
| Mar. 7 | 41·76 | W. | I. | 6 56 31·01 | 32·43 | +1·42 | −1·68 | −0·26 | N. | 63 4 47·84 | 47·51 | − 0·33 | − 1·01 | −1·34 |
| 8 | 41·76 | R. | I. | 7 55 33·50 | 34·95 | +1·45 | −1·61 | −0·16 | N. | 64 26 35·47 | 38·51 | + 3·04 | − 3·50 | −0·46 |
| 9 | 41·76 | F.B. | I. | 8 51 27·19 | 28·64 | +1·45 | −1·52 | −0·07 | N. | 67 10 11·16 | 14·47 | + 3·31 | − 5·58 | −2·27 |
| 10 | 41·77 | F.B. | I. | 9 43 46·97 | 48·30 | +1·33 | −1·42 | −0·09 | N. | 70 58 50·23 | 56·72 | + 6·49 | − 7·18 | −0·69 |
| 11 | 41·77 | R. | I. | 10 32 46·55 | 47·55 | +1·00 | −1·34 | −0·34 | N. | 75 35 29·77 | 37·80 | + 8·03 | − 8·31 | −0·28 |

| Day, 1892. | Correction to be subtracted from M.T. for Change of Sidereal Time at Mean Noon since 1864. | Observer. | Limb observed in R.A. | Observed R.A. | R.A. from Hansen's Tables for Uncorrected Mean Times. | Hansen *minus* Observed. **Uncorrected.** | Correction due to the Change in the Unit of Mean Time. | Hansen *minus* Observed. **Corrected.** | Limb observed in N.P.D. | Observed N.P.D. | N.P.D. from Hansen's Tables for Uncorrected Mean Times. | Hansen *minus* Observed. **Uncorrected.** | Correction due to the Change in the Unit of Mean Time. | Hansen *minus* Observed. **Corrected.** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | s | | | h m s | s | s | s | s | | ° ′ ″ | ″ | ″ | ″ | ″ |
| Mar. 12 | 41·78 | F.B. | I. | 11 19 4·06 | 5·25 | +1·19 | −1·27 | −0·08 | N. | 80 44 22·97 | 31·53 | +8·56 | −9·03 | −0·47 |
| 18 | 41·80 | W. | II. | 15 51 17·51 | 18·96 | +1·45 | −1·43 | +0·02 | S. | 111 17 28·58 | 35·84 | +7·26 | −6·22 | +1·04 |
| 20 | 41·81 | R. | II. | 17 40 7·32 | 8·59 | +1·27 | −1·62 | −0·35 | S. | 116 31 50·64 | 53·21 | +2·57 | −2·31 | +0·26 |
| Apr. 4 | 41·87 | W. | I. | 7 37 9·89 | 11·23 | +1·34 | −1·66 | −0·32 | N. | 63 39 36·14 | 37·93 | +1·79 | −2·82 | −1·03 |
| 5 | 41·87 | R. | I. | 8 34 38·08 | 39·41 | +1·33 | −1·56 | −0·23 | N. | 66 1 36·43 | 41·47 | +5·04 | −5·06 | −0·02 |
| 6 | 1·88 | F.B. | I. | 9 28 7·35 | 8·51 | +1·16 | −1·45 | −0·29 | N. | 69 33 48·60 | 54·04 | +5·44 | −6·79 | −1·35 |
| 7 | 41·88 | W. | I. | 10 17 52·28 | 53·41 | +1·13 | −1·36 | −0·23 | N. | 73 58 2·86 | 10·28 | +7·42 | −8·04 | −0·62 |
| 8 | 41·88 | R. | I. | 11 4 35·92 | 36·94 | +1·02 | −1·29 | −0·27 | N. | 78 58 20·90 | 29·30 | +8·40 | −8·86 | −0·46 |
| 9 | 41·89 | F.B. | I. | 11 49 13·47 | 14·59 | +1·12 | −1·24 | −0·12 | N. | 84 21 2·89 | 11·44 | +8·55 | −9·33 | −0·78 |
| 11 | 41·90 | W | I. | 13 16 7·75 | 8·82 | +1·07 | −1·24 | −0·17 | N. & S. | 95 26 52·39 | 61·40 | +9·01 | −9·30 | −0·29 |
| 17 | 41·92 | R. | II. | 18 18 21·22 | 22·29 | +1·07 | −1·64 | −0·57 | N. | 117 15 16·68 | 18·89 | +2·21 | −0·67 | +1·54 |
| May 6 | 42·00 | R. | I. | 11 34 47·56 | 48·47 | +0·91 | −1·26 | −0·35 | N. | 82 30 17·18 | 26·49 | +9·31 | −9·26 | +0·05 |
| 9 | 42·01 | W. | I. | 13 45 29·37 | 30·34 | +0·97 | −1·26 | −0·29 | N. | 99 2 6·64 | 14·39 | +7·75 | −9·06 | −1·31 |
| 10 | 42·01 | R. | I. | 14 30 49·07 | 50·12 | +1·05 | −1·31 | −0·26 | N. | 104 10 16·87 | 24·88 | +8·01 | −8·36 | −0·35 |
| 12 | 2·02 | F.B. | II. | 16 9 19·57 | 20·95 | +1·38 | −1·48 | −0·10 | S. | 112 39 11·08 | 19·17 | +8·09 | −5·75 | +2·34 |
| 14 | 42·03 | R. | II. | 18 0 17·61 | 18·79 | +1·18 | −1·63 | −0·45 | S. | 117 4 14·43 | 16·59 | +2·16 | −1·46 | +0·70 |
| 18 | 42·04 | R. | II. | 21 52 47·03 | 48·64 | +1·61 | −1·56 | +0·05 | N. | 108 26 56·56 | 48·12 | −8·44 | +8·33 | −0·11 |
| June 1 | | R. | I. | 12 2 45·14 | 45·99 | +0·85 | −1·25 | −0·40 | N. | 86 3 53·54 | 61·66 | +8·12 | −9·51 | −1·39 |

| Day, 1892. | Correction to be subtracted from M.T. for Change of Sidereal Time at Mean Noon since 1864. | Observer. | Limb observed in R.A. | Observed R.A. | R.A. from Hansen's Tables for Uncorrected Mean Times. | Hansen *minus* Observed. **Uncorrected.** | Correction due to the Change in the Unit of Mean Time. | Hansen *minus* Observed. **Corrected.** | Limb observed in N.P.D. | Observed N.P.D. | N.P.D. from Hansen's Tables for Uncorrected Mean Times. | Hansen *minus* Observed. **Uncorrected.** | Correction due to the Change in the Unit of Mean Time. | Hansen *minus* Observed. **Corrected.** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | s | | | h m s | s | s | s | s | | ° ′ ″ | ″ | ″ | ″ | ″ |
| June 6 | 42·12 | F.B. | I. | 14 14 19·77 | 21·18 | +1·41 | −1·30 | +0·11 | N. | 102 24 36·10 | 43·54 | +7·44 | −8·66 | −1·22 |
| | 42·12 | R. | I. | 15 1 11·72 | 12·74 | +1·02 | −1·37 | −0·35 | N. | 107 13 58·80 | 66·27 | +7·47 | −7·70 | −0·23 |
| 7 | 42·12 | R. | I. | 15 1 11·72 | 12·74 | +1·02 | −1·37 | −0·35 | N. | 107 13 58·80 | 66·27 | +7·47 | −7·70 | −0·23 |
| 8 | 42·13 | F.B. | I. | 15 51 3·13 | 4·41 | +1·28 | −1·46 | −0·18 | N. | 111 23 41·40 | 46·29 | +4·89 | −6·36 | −1·47 |
| 9 | 42·13 | W. | I. | 16 44 22·11 | 23·38 | +1·27 | −1·55 | −0·28 | N. & S. | 114 37 47·59 | 53·37 | +5·78 | −4·54 | +1·24 |
| 12 | 42·14 | R. | II. | 19 39 47·51 | 49·05 | +1·54 | −1·68 | −0·14 | N. | 116 16 11·10 | 10·33 | −0·77 | +3·01 | +2·24 |
| 13 | 42·15 | F.B. | II. | 20 38 46·93 | 48·84 | +1·91 | −1·64 | +0·27 | N. | 113 43 33·39 | 31·13 | −2·26 | +5·55 | +3·29 |
| 14 | 42·15 | W. | II. | 21 35 48·52 | 50·35 | +1·83 | −1·58 | +0·25 | N. | 109 46 49·18 | 44·13 | −5·05 | +7·75 | +2·70 |
| 17 | 42·16 | F.B. | II. | 0 15 19·88 | 21·42 | +1·54 | −1·47 | +0·07 | N. | 92 13 69·38 | 56·91 | −12·47 | +11·33 | −1·14 |
| 30 | 42·22 | W. | I. | 11 44 41·85 | 42·89 | +1·04 | −1·28 | −0·24 | N. | 83 58 32·66 | 40·75 | +8·09 | −9·58 | −1·49 |
| July 7 | 42·24 | W. | I. | 17 18 35·65 | 36·96 | +1·31 | −1·62 | −0·31 | S. & N. | 116 4 8·78 | 10·73 | +1·95 | −3·16 | −1·21 |
| Aug. 4 | 42·36 | W. | I. | 17 51 37·63 | 39·01 | +1·38 | −1·67 | −0·29 | S. | 117 1 49·72 | 48·64 | −1·08 | −1·69 | −2·77 |
| 5 | 42·36 | R. | I. | 18 51 33·36 | 34·73 | +1·37 | −1·72 | −0·35 | S. | 117 14 44·81 | 40·70 | −4·11 | +1·01 | −3·10 |
| 12 | 42·39 | W. | II. | 1 27 18·37 | 20·04 | +1·67 | −1·52 | +0·15 | N. | 82 33 51·12 | 39·20 | −11·92 | +11·29 | −0·63 |
| Sept. 5 | 42·48 | W. | I. | 22 21 20·77 | 22·28 | +1·51 | −1·61 | −0·10 | S. | 105 19 40·60 | 30·99 | −9·61 | +9·98 | +0·37 |
| 7 | 42·49 | W. | II. | 0 11 36·69 | 38·26 | +1·57 | −1·55 | +0·02 | N. | 92 7 45·52 | 33·55 | −11·97 | +12·09 | +0·12 |
| 8 | 42·50 | R. | II. | 1 6 3·10 | 4·37 | +1·27 | −1·56 | −0·29 | N. | 85 2 66·84 | 55·74 | −11·10 | +11·99 | +0·89 |
| Oct. 1 | 42·59 | W. | I. | 20 55 27·01 | 28·38 | +1·37 | −1·65 | −0·28 | S. | 112 48 38·19 | 32·44 | −5·75 | +6·65 | +0·90 |
| 3 | 42·60 | R. | I. | 22 48 38·41 | 39·60 | +1·19 | −1·58 | −0·39 | S. | 102 26 32·38 | 21·44 | −10·94 | +10·79 | −0·15 |

| Day, 1892. | Correction to be subtracted from M.T. for Change of Sidereal Time at Mean Noon since 1864. | Observer. | Limb observed in R.A. | Observed R.A. | R.A. from Hansen's Tables for Uncorrected Mean Times. | Hansen *minus* Observed. **Uncorrected.** | Correction due to the Change in the Unit of Mean Time. | Hansen *minus* Observed. **Corrected.** | Limb observed in N.P.D. | Observed N.P.D. | N.P.D. from Hansen's Tables for Uncorrected Mean Times. | Hansen *minus* Observed. **Uncorrected.** | Correction due to the Change in the Unit of Mean Time. | Hansen *minus* Observed. **Corrected.** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | s | | | h m s | s | s | s | s | | ° ′ ″ | ″ | ″ | ″ | ″ |
| Oct. 5 | 42·60 | R. | I. | 0 38 28·39 | 29·66 | +1·27 | −1·58 | −0·31 | S. | 88 35 46·82 | 35·19 | −11·63 | +12·44 | +0·81 |
| 10 | 42·62 | R. | II. | 5 43 45·35 | 47·06 | +1·71 | −1·87 | −0·16 | N. | 62 39 23·83 | 21·77 | −2·06 | +2·24 | +0·18 |
| Nov. 1 | 42·71 | R. | I. | 0 9 13·70 | 14·72 | +1·02 | −1·54 | −0·52 | S. | 92 28 11·16 | 1·67 | −9·49 | +12·15 | +2·66 |
| 3 | 42·72 | R. | I. | 2 0 40·21 | 41·40 | +1·19 | −1·67 | −0·48 | S. | 78 16 27·66 | 16·23 | −11·43 | +11·65 | +0·22 |
| 5 | 42·73 | R. | II. | 4 5 21·38 | 22·83 | +1·45 | −1·88 | −0·43 | N. | 66 47 61·08 | 55·43 | −5·65 | +7·33 | +1·68 |
| 29 | 42·82 | R. | I. | 0 37 4·69 | 5·72 | +1·03 | −1·51 | −0·48 | S. | 88 43 66·29 | 55·95 | −10·34 | +11·90 | +1·56 |
| 30 | 42·83 | R. | I. | 1 30 50·17 | 51·28 | +1·11 | −1·58 | −0·47 | S. | 81 49 12·48 | 2·33 | −10·15 | +11·76 | +1·61 |
| Dec. 3 | 42·84 | W. | I. & II. | 4 35 24·83 | 26·44 | +1·61 | −1·93 | −0·32 | N. | 65 4 56·82 | 50·50 | −6·32 | +5·88 | −0·44 |
| 12 | 42·88 | R. | II. | 13 3 6·81 | 7·78 | +0·97 | −1·26 | −0·29 | S. | 94 44 1·55 | 7·00 | +5·45 | −9·79 | −4·34 |
| 24 | 42·92 | R. | I. | 22 37 17·33 | 18·41 | +1·08 | −1·48 | −0·40 | S. | 103 28 43·89 | 33·85 | −10·04 | +9·79 | −0·25 |
| 26 | 42·93 | W. | I. | 0 17 58·41 | 59·49 | +1·08 | −1·46 | −0·38 | S. | 91 1 33·43 | 23·36 | −10·07 | +11·47 | +1·40 |
| 29 | 42·94 | R. | I. | 2 59 45·58 | 46·80 | +1·22 | −1·71 | −0·49 | S. | 71 52 58·39 | 48·73 | −9·66 | +9·52 | −0·14 |
| 30 | 42·95 | W. | I. | 4 1 42·48 | 43·80 | +1·32 | −1·84 | −0·52 | S. | 66 58 16·66 | 10·13 | −6·53 | +7·22 | +0·69 |
| **Mean of Errors, without regard to sign** | | | | | ... | s 1·290 | ... | s 0·263 | | ... | ... | ″ 6·696 | ... | ″ 1·117 |
| **Mean Errors for Year** | | | | ... ... ... | ... | +1·290 | ... | −0·233 | | | | | | |

*Observers*: W., Mr. W. Wickham; R., Mr. W. H. Robinson; F.B., Mr. F. A. Bellamy.

TABLE II.

*Radcliffe Observations of the Moon*, 1892.

*Errors of the Moon's Tabular Place in Longitude and Ecliptic Polar Distance,* **Uncorrected** *and* **Corrected** *for the Change in the Unit of Mean Time introduced in the year* 1864.

| Day, 1892. | | Observer. | Limb observed in R.A. | Limb observed in N.P.D. | Errors of Longitude (Hansen *minus* Observed). | | Errors of E.N.P.D. (Hansen *minus* Observed). | |
|---|---|---|---|---|---|---|---|---|
| | | | | | **Uncorrected.** | **Corrected.** | **Uncorrected.** | **Corrected.** |
| | | | | | " | " | " | " |
| Jan. | 6 | F.B. | I. | S. | +22·68 | −1·84 | −1·11 | +0·50 |
| | 7 | W. | I. | S. | +22·92 | −1·41 | −1·56 | +0·35 |
| | 11 | F.B. | I. | N. | +20·38 | −3·22 | −1·59 | +0 23 |
| | 13 | R. | I. & II. | N. | +17·60 | −5·11 | −1·28 | −0·23 |
| | 15 | R. | II. | S. | +17·16 | −4·71 | −0·01 | +0·20 |
| Feb. | 3 | F.B. | I. | S. | +21·43 | −3·42 | −2·16 | −0·29 |
| | 8 | R. | I. | N. | +18·35 | −4·56 | −1·46 | +0·06 |
| | 11 | F.B. | I. | N. | +20·04 | −1·85 | −1·06 | −0 78 |
| | 16 | F.B. | II. | S. | +19·01 | −1·58 | −1·16 | −2·61 |
| Mar. | 7 | W. | I. | N. | +18·90 | −3·60 | −2·16 | −1·00 |
| | 8 | R. | I. | N. | +19·92 | −2·22 | −0·82 | −0·03 |
| | 9 | F.B. | I. | N. | +20 27 | −1·56 | −2·28 | −1·92 |
| | 10 | F.B. | I. | N. | +20·02 | −1·44 | −0·13 | −0·23 |
| | 11 | R. | I. | N. | +16·55 | −4·71 | +2·08 | +1·57 |
| | 12 | F.B. | I. | N. | +19 61 | −1·28 | +0·95 | +0·03 |
| | 18 | W. | II. | S. | +21·35 | +0·49 | +2·82 | +0·96 |
| | 20 | R. | II. | S. | +17·15 | −4·69 | +1·97 | +0·43 |
| Apr. | 4 | W. | I. | N. | +18·09 | −4·42 | −1·22 | −0·30 |
| | 5 | R. | I. | N. | +18·99 | −3·07 | +0 35 | +0·77 |
| | 6 | F.B. | I. | N. | +17·27 | −4·31 | +0·02 | 0·00 |
| | 7 | W. | I. | N. | +17·95 | −3·33 | +1·05 | +0·62 |
| | 8 | R. | I. | N. | +17·17 | −3·86 | +1·93 | +1·11 |
| | 9 | F.B. | I. | N. | +18 83 | −1·96 | +1·17 | 0·00 |
| | 11 | W. | I. | N. & S. | +18·24 | −2·47 | +2·32 | +0·69 |
| | 17 | R. | II. | N. | +14·23 | −7·66 | +2·64 | +1·31 |
| May | 6 | R. | I. | N. | +16·16 | −4·77 | +3·18 | +2·11 |
| | 9 | W. | I. | N. | +16·21 | −4·49 | +2·11 | +0·31 |
| | 10 | R. | I. | N. | +17·01 | −3·70 | +2·78 | +0·86 |
| | 12 | F.B. | II. | S. | +20·31 | −0·93 | +4·41 | +2·55 |
| | 14 | R. | II. | S. | +15·79 | −6·02 | +2·16 | +0·70 |
| | 18 | R. | II. | N. | +24·56 | +0·71 | −0·16 | +0 14 |

| Day, 1892. | Observer. | Limb observed in R.A. | Limb observed in N.P.D. | Errors of Longitude (Hansen *minus* Observed). Uncorrected. | Errors of Longitude (Hansen *minus* Observed). Corrected. | Errors of E.N.P.D (Hansen *minus* Observed). Uncorrected. | Errors of E.N.P.D (Hansen *minus* Observed). Corrected. |
|---|---|---|---|---|---|---|---|
| June 3 | R. | I. | N. | +14″·95 | −6″·06 | +2″·37 | +1″·11 |
| 6 | F.B. | I. | N. | +21·96 | +1·11 | +0·17 | −1·69 |
| 7 | R. | I. | N. | +16·13 | −4·88 | +3·09 | +1·18 |
| 8 | F.B. | I. | N. | +18·50 | −2·77 | +1·02 | −0·91 |
| 9 | W. | I. | N. & S. | +17·95 | −3·63 | +3·51 | +1·72 |
| 12 | R. | II. | N. | +20·63 | −2·24 | +2·74 | +1·89 |
| 13 | F.B. | II. | N. | +26·06 | +2·76 | +4·50 | +4·13 |
| 14 | W. | II. | N. | +26·18 | +2·48 | +3 58 | +3·70 |
| 17 | F.B. | II. | N. | +26·24 | +1·42 | −2·28 | −0·63 |
| June 30 | W. | I. | N. | +17·51 | −3·89 | +1·25 | +0·06 |
| July 7 | W. | I. | S. & N. | +17·78 | −4·26 | +0·66 | −0·90 |
| Aug. 4 | W. | I. | S. | +18·46 | −3·92 | −1·33 | −2·72 |
| 5 | R. | I. | S. | +18·62 | −4 38 | −2·45 | −3·51 |
| 12 | W. | II. | N. | +27·52 | +2·31 | −1·89 | +0·24 |
| Sept. 5 | W. | I. | S. | +23·92 | −1·49 | −1·01 | −0·18 |
| 7 | W. | II. | N. | +26·43 | +0·23 | −1·63 | +0·23 |
| 8 | R. | II. | N. | +21·80 | −4·35 | −3·02 | −0·83 |
| Oct. 1 | W. | I. | S. | +19·88 | −3·99 | −0·28 | −0·21 |
| 3 | R. | I. | S. | +20·34 | −5·24 | −3·49 | −2·31 |
| 5 | R. | I. | S. | +22·15 | −4·60 | −3·23 | −1·08 |
| 10 | R. | II. | N. | +22·85 | −2·14 | −1·43 | +0·12 |
| Nov. 1 | R. | I. | S. | +17·87 | −8·24 | −2·62 | −0·66 |
| 3 | R. | I. | S. | +20·34 | −6 69 | −4·69 | −2·23 |
| 5 | R. | II. | N. | +20·69 | −6·14 | −1·76 | +0 53 |
| Nov. 29 | R. | I. | S. | +18·32 | −7·25 | −3·44 | −1·40 |
| 30 | R. | I. | S. | +19 03 | −7·07 | −3·38 | −1·07 |
| Dec. 3 | W. | I. & II. | N. | +22·60 | −4·25 | −3·13 | −1·06 |
| 12 | R. | II. | S. | +15·49 | −5·67 | −0·52 | −2·35 |
| Dec. 24 | R. | I. | S. | +18·43 | −5·33 | −3·41 | −2·42 |
| 26 | W. | I. | S. | +18·92 | −5·80 | −2·82 | −0·98 |
| 29 | R. | I. | S. | +19·41 | −6·66 | −4·36 | −2·10 |
| 30 | W. | I. | S. | +19·17 | −7·18 | −2·83 | −0·73 |
| **Mean of Errors, without regard to sign ... ... ...** | | | | 19″·687 | 3″·775 | 2″·032 | 1″·076 |
| **Mean Errors for Year ... ...** | | | | +19″·687 | −3″·410 | ... | .. |

TABLE III.

*Mean Excess over Observation of the Moon's Tabular Place in Longitude for the years* 1847 *to* 1892, *as computed from Hansen's Tables.*

**Uncorrected** *and* **Corrected** *for the change in the Unit of Mean Time introduced in the year* 1864.

| Year. | Errors of Longitude (Hansen *minus* Observed). **Uncorrected.** | **Corrected.** | |
|---|---|---|---|
| | ″ | ″ | |
| 1847 | + 0·51 | + 0·51 | Mean Annual Error in Longitude from 1847 to 1863 = − 1″·85. |
| 1848 | − 0·53 | − 0·53 | |
| 1849 | − 1·08 | − 1·08 | |
| 1850 | − 0·97 | − 0·97 | |
| 1851 | − 1·93 | − 1·93 | |
| 1852 | − 1·57 | − 1·57 | |
| 1853 | − 2·18 | − 2·18 | |
| 1854 | − 2·34 | − 2·34 | |
| 1855 | − 1·40 | − 1·40 | |
| 1856 | − 1·51 | − 1·51 | |
| 1857 | − 2·41 | − 2·41 | |
| 1858 | − 2·61 | − 2·61 | |
| 1859 | − 2·49 | − 2·49 | |
| 1860 | − 3·62 | − 3·62 | |
| 1861 | − 2·95 | − 2·95 | |
| 1862 | − 2·83 | − 2·83 | |
| 1863 | − 1·61 | − 1·61 | |
| 1864 | + 0·12 | − 0·81 | Mean Annual Error in Longitude from 1864 to 1892 (taken out with the corrected argument) = − 1″·56. |
| 1865 | + 1·27 | − 0·22 | |
| 1866 | + 2·14 | − 0·22 | |
| 1867 | + 3·48 | + 0·36 | |
| 1868 | + 4·12 | + 0·28 | |
| 1869 | + 4·28 | − 0·35 | |
| 1870 | + 4·83 | − 0·66 | |
| 1871 | + 6·96 | + 0·44 | |
| 1872 | + 7·31 | + 0·10 | |
| 1873 | + 8·24 | + 0·20 | |
| 1874 | + 9·29 | + 0·56 | |
| 1875 | + 9·87 | + 0·36 | |
| 1876 | + 9·80 | − 0·50 | |
| 1877 | + 9·23 | − 1·90 | |
| 1878 | + 8·22 | − 3·60 | |
| 1879 | + 9·63 | − 3·12 | |
| 1880 | + 10·89 | − 2·77 | |
| 1881 | + 10·51 | − 4·06 | |
| 1882 | + 12·68 | − 2·51 | |
| 1883 | + 14·71 | − 1·50 | |
| 1884 | + 14·65 | − 1·91 | |
| 1885 | + 15·20 | − 1·82 | |
| 1886 | + 15·34 | − 2·53 | |
| 1887 | + 15·70 | − 3·25 | |
| 1888 | + 17·68 | − 2·46 | |
| 1889 | + 17·37 | − 3·51 | |
| 1890 | + 18·02 | − 3·55 | |
| 1891 | + 19·30 | − 2·90 | |
| 1892 | + 19·69 | − 3·41 | |

1847 to 1879: Greenwich observations. 1880 to 1882: Mean of Greenwich and Radcliffe. 1883 to 1892: Radcliffe observations.

*Radcliffe Observatory, Oxford:*
1893 *November* 9.

*Preliminary Note on the Reduction of Measures of Photographic Plates.* By H. H. Turner, M.A., B.Sc.

1. The following is an attempt to simplify the processes already suggested for the reduction of measures of stellar photographs, and especially measures of the plates of the Astrographic Chart.

2. The fundamental property of a photographic plate is that it is a projection of the celestial sphere from a point (the centre of the object-glass) on a plane (the photographic plate itself). This statement must be qualified just so far as the image of the star is displaced by—

(*a*) Distortion of the objective;
(*b*) Displacements of the photographic film;
(*c*) Refraction and aberration.

3. Neglecting for the moment these disturbing causes, it follows that any great circle on the sphere projects into a straight line on the plate; and any straight line on the plate corresponds to a great circle on the sphere, and hence to a straight line on any other plate containing the same region.

4. The appropriateness of using rectilinear co-ordinates is thus suggested: for the transformation from any rectilinear co-ordinates on one plate to any rectilinear on another takes a simple form. Let $(x, y)$, $(\xi, \eta)$ be any rectilinear co-ordinates of the same point on the two plates; then the following general relations hold:

$$\xi = \frac{Ax + By + C}{Kx + Ly + M}, \qquad \eta = \frac{Dx + Ey + F}{Kx + Ly + M}.$$

It is readily seen that the denominator must be the same in the two cases, for the equation

$$\lambda\xi + \mu\eta + \nu = 0$$

represents a straight line on one plate for all values of $\lambda$, $\mu$, $\nu$, and hence must represent a straight line on the other. The above formulæ give the equation to this straight line, viz.

$$\lambda\,(Ax + By + C) + \mu(Dx + Ey + F) + \nu(Kx + Ly + M) = 0.$$

5. The above formulæ are quite general, but a more convenient form may be given to them in the case of co-ordinates measured approximately in similar directions on the two plates, as will generally be the case for the plates of the Astrographic Chart. We shall then have *approximately*

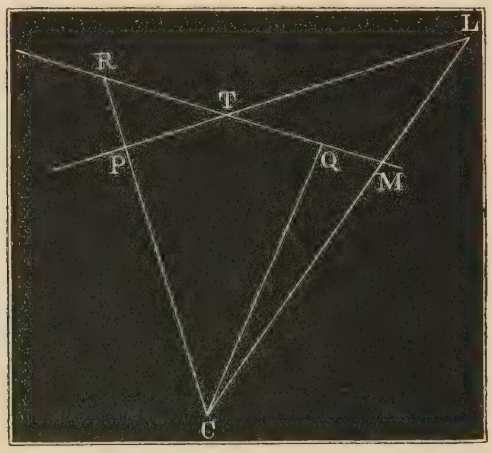
$$\xi = x + \text{const.}, \qquad \eta = y + \text{const.},$$

and the accurate relations may be written

$$\xi = \frac{(1+a)\,x + by + c}{1 - kx - ly}, \qquad \eta = \frac{dx + (1+e)\,y + f}{1 - kx - ly},$$

where $a$, $b$, $d$, $e$, $k$, $l$ are all small, and $c$ and $f$ are the co-ordinates of the centre of the plate $(x, y)$ on the plate $(\xi, \eta)$, which are about 1° in the case of the chart plates.

6. The meaning of the denominator may be seen most readily by taking a simple case. Let C be the centre of the sphere,




PTL, RTM two plates whose centres are P and Q; L and M the images of a star on these plates, in a plane through PCQ; PL, QM the co-ordinates $x$ and $\xi$. Then if the radius CP of the sphere be taken as unity

$$\xi = \mathrm{QM} = \tan \mathrm{QCM} = \tan(\mathrm{PCL} - \mathrm{RCQ})$$

$$= \frac{\mathrm{PL} - \mathrm{RQ}}{1 + \mathrm{PL} \,.\, \mathrm{RQ}}$$

$$= \frac{x - \mathrm{RQ}}{1 + x \,.\, \overline{\mathrm{RQ}}}$$

$$= \frac{x + c}{1 - kx},$$

where $k = c = -\mathrm{RQ}$ = the $x$ co-ordinate of centre of plate $(x, y)$ on plate $(\xi, \eta)$. And it can be shown generally that if $(x, y)$ $(\xi, \eta)$ are measured from the centres of the two plates, our general formulæ of transformation become

$$\xi = \frac{(1+a)\,x + by + c}{1 - cx - fy}, \qquad \eta = \frac{dx + (1+e)\,y + f}{1 - cx - fy},*$$

where all the quantities are in parts of the radius. If, as is usual in measuring the Astrographic Chart plates, $x$ and $y$ (and consequently $c$ and $f$) be expressed in minutes (or seconds) of arc, instead of $k=c$, $l=f$, we shall have

$$k = \frac{c}{(3438)^2} \text{ or } \frac{c}{(206264)^2}, \text{ \&c.}$$

7. Such formulæ hold whether the co-ordinates be measured accurately in prescribed directions or not, provided they are rectilinear, but we shall often find it useful to refer to what may be called the standard co-ordinates of a plate, which are thus defined: Let A and P be the Right Ascension and N.P.D. for 1900·0 of the proposed centre of the plate; from this point draw two straight lines on the tangent plane to the celestial sphere perpendicular and parallel to the meridian for 1900·0. These lines are the axes of $\xi$, and $\eta$, and $(\xi, \eta)$, the "standard co-ordinates" of any point whose R.A. and N.P.D. and $\alpha$ and $p$ respectively, are expressible in terms of these quantities by the relations

$$\xi = \frac{\tan(\alpha - A)\sin q}{\cos(P - q)}, \qquad \eta = \tan(P - q),$$

where

$$\tan q = \tan p \cos(\alpha - A).$$

(See Note I.)

8. Let us now return to the disturbing causes mentioned in paragraph 2. Concerning distortion of the object-glass and displacements of the photographic film it is to be remarked, in the first place, that they have been shown to be small; and, secondly, that any correction for them falls outside this or any other general method of reduction. As regards

*Refraction*, various formulæ have been given for the differential refraction, perhaps the most elegant being those of Dr. A. A. Rambaut in *Astronomische Nachrichten*, No. 3125. He there shows that it is only necessary to retain terms of the first order in $\Delta\alpha \cos\delta$, and $\Delta\delta$, and finds the following expressions:—

$$\Delta d\alpha = \beta_0 \left( \frac{\cos\phi}{\cos\delta} \frac{\sin\nu \sin(\mu+\delta)}{\sin^2 n \sin^2(m+\delta)} d\alpha + \frac{\cot n \cos(m+2\delta)}{\cos^2\delta \sin^2(m+\delta)} d\delta \right),$$

$$\Delta d\delta = \beta_0 \left( \frac{\cos\phi \cos\nu}{\sin^2 n \,.\, \sin^2(m+\delta)} d\alpha + \frac{1}{\sin^2(m+\delta)} d\delta \right);$$

* These formulæ are approximate only. Generally $(c, f)$ are the co-ordinates of centre of plate $(x, y)$ on plate $(\xi, \eta)$ and $(-k, -l)$ the co-ordinates of centre of $(\xi, \eta)$ on $(x, y)$, but in the small terms involving $(k, l)$ these are sensibly equal. (See Note IV.)

where

$$\tan m = \cot \phi \cos(\theta - \alpha) \qquad \cot \mu = \tan \phi \cos(\theta - \alpha)$$

$$\cot n = \sin m \tan(\theta - \alpha) \qquad \cot \nu = \cos \mu \tan(\theta - \alpha).$$

Elegant as these formulæ are, much simpler ones can be obtained by using rectangular co-ordinates on the plate instead of R.A. and Declination. Let X and Y be the "standard co-ordinates" (see paragraph 7) of the zenith, supposed projected on the plate. If $\lambda$ be the colatitude, S the sidereal time of exposure of the plate, A and P the R.A. and N.P.D. of the centre, according to the formulæ in paragraph 7, we have

$$X = \frac{\tan(S-A)\sin q}{\cos(P-q)}, \qquad Y = \tan(P-q),$$

where

$$\tan q = \tan \lambda \cos(S-A).$$

These formulæ are very simple, and $q$ can readily be tabulated at any given place for different values of the hour angle S−A. Then it is shown in Note II. that the corrections for refraction become

$$d\xi = \beta_0\{(1+X^2)\xi + XY\eta\}$$

$$d\eta = \beta_0\{XY\,.\,\xi + (1+Y^2)\eta\},$$

where $\beta_0$ is the constant of refraction, as in Dr. Rambaut's formulæ. But the point of greatest importance is the preliminary investigation of Dr. Rambaut's paper, which shows that terms of the second order in $\xi$ and $\eta$ may be neglected, and makes the above corrections *linear* in $\xi$ and $\eta$; for thus it follows that a straight line on the plate is still a straight line, and hence the correction for refraction is *included* in the general formulæ quoted above. No separate calculation of the refraction is therefore required. Similarly the correction for

*Aberration* is small, and all terms beyond those of the first order may be neglected. If (X′, Y′) be the co-ordinates of the "Earth's Way" supposed projected on the plate, the corrections for aberration are shown in Note III. to be

$$dx = \frac{\gamma_0 x}{\sqrt{1+X'^2+Y'^2}}$$

$$dy = \frac{\gamma_0 y}{\sqrt{1+X'^2+Y'^2}}.$$

These again, being linear, are included in the general formulæ, and no separate calculation of them is required.

9. The following corrections are also well known to involve

linear transformations only, and are similarly included in the general formulæ :—

That for orientation, whether of the plate in the telescope or in the measuring apparatus.

That for scale value, whether due to change in focal length of the telescope or in the measuring apparatus.

That for non-perpendicularity of the two measured co-ordinates.

10. It follows, then, that if $(x, y)$ be the measured rectilinear co-ordinates of a star on a plate as affected by refraction, aberration, and the sources of error mentioned above ; and if $(\xi, \eta)$ be its "standard co-ordinates" (see paragraph 7) and $\kappa$ is the number of minutes of arc in the radian : then

$$\kappa\xi = (1 + \alpha)x + \beta y + \gamma, \qquad \kappa\eta = \delta x + (1 + \epsilon)y + \zeta,$$

no denominator being required in these expressions if the theoretical and actual centres of the plate are nearly coincident. Now, if there are three known stars on the plate, we have six equations to determine the constants $\alpha$, $\beta$, $\gamma$, $\delta$, $\epsilon$, $\zeta$ ; or, if more stars are known, we can solve by least squares or any analogous process. It is to be noted that the equations are of the linear form specially adapted to simple solution. Knowing these constants we can convert the measured co-ordinates $(x, y)$ of any star into standard co-ordinates $(\xi, \eta)$, and *if desired* into R.A. and N.P.D. by the formulæ of paragraph 7 : viz. find $q$ from

$$\tan (\mathrm{P} - q) = \eta,$$

then $\alpha$ from

$$\frac{\tan (\alpha - \mathrm{A}) \sin q}{\cos (\mathrm{P} - q)} = \xi,$$

and finally $p$ from $\tan q = \tan p \cos (\alpha - \mathrm{A})$. But I venture to think that this final transformation will generally be unnecessary, for the "standard co-ordinates" of a star will for many purposes be far more convenient.

11. If there be not enough known stars on the plate to give a good determination of the constants $\alpha$, $\beta$, $\gamma$, &c., it becomes necessary to associate with it neighbouring plates in the manner suggested by M. Loewy. The process he adopts is, however, much simplified by the present method. If we have a central plate (0), and four others (1), (2), (3), (4), whose centres are approximately at the corners of the plate (0), and if suffixes denote the fact that the co-ordinates are measured on the corresponding plate, then we have

$$x_0 = \frac{(1+a)\,x_1 + by_1 + c}{1 - \mu c x_1 - \mu f y_1}$$

$$y_0 = \frac{dx_1 + (1+e)\,y_1 + f}{1 - \mu c x_1 - \mu f y_1},$$

where

$$\mu = \frac{1}{(343'')^2}$$

and the quantities are in minutes of arc. Since the quantities $\mu c x_1 x_0$, $\mu f y_1 x_0$, &c., are very small, approximate values of $c$ and $f$, such as can be found by mere inspection, will be sufficiently accurate for substitution in these terms, and we can form the quantities

$$x_0\,(1 - \mu c x_1 - \mu f y_1)$$
$$y_0\,(1 - \mu c x_1 - \mu f y_1)$$

for all the stars common to the two plates. We then have for each star two simple equations in $a$, $b$, $c$, $d$, $e$, $f$, and all these may be solved by least squares or any analogous process.

Knowing $a$, $b$, $c$, $d$, $e$, $f$, we can form $(x_0, y_0)$ the co-ordinates of any star $(x_1 y_1)$ on the plate (1), but outside the region common to the two plates, *as though that star had been on the plate* (0) *and measured with the other stars on the same system.* We can thus virtually transfer all the known stars on the plates (1), (2), (3), (4) on to the plate (0), and increase the number of the equations for determining $\alpha$, $\beta$, $\gamma$, &c., on that plate. The process is obviously capable of indefinite extension.

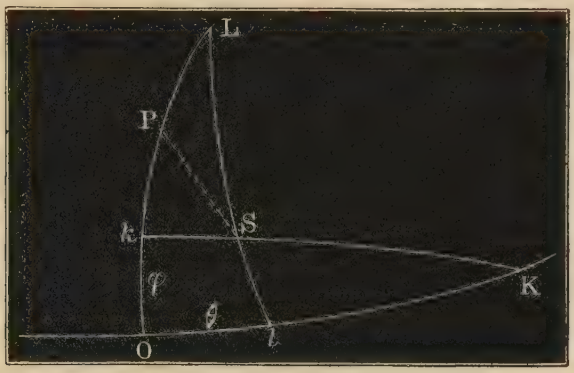
12. In view of this method of reduction by rectilinear co-ordinates, a recent decision of the Permanent Committee to publish such measures without further reduction becomes very important. It is clear that from such measures—

(1) Formulæ can quickly be deduced connecting one plate with another.

(2) The use of Right Ascensions and Declinations may be entirely deferred until we wish to deduce the final constants for any plate from known stars. Indeed, a great deal of information as to the progress of the work generally can be obtained without ever using R.A. and Declination at all, when it is once realised that measures on one plate are very simply convertible into measures on another. Rectilinear measures, instead of being very raw material, are, in fact, quite ready for use. They are readily comparable *inter se*, and with any similar measures of similar photographs to be made in the future. R.A. and Declination are a necessity of meridian and equatorial observation, but only complicate any discussion of the places of the stars.

*Note I.*

Let O be the centre of the plate, K and L its poles on the celestial sphere; P the North Pole of the heavens.




Let the R.A. of the centre O be A, and its N.P.D., P; and let $(\alpha, p)$ be the R.A. and N.P.D. of any star S on the plate. Then

$$PS = p, \quad \angle OPS = \alpha - A, \quad OP = P;$$

$$\xi = \tan Ol = \tan \theta \text{ (say)}, \quad \eta = \tan Ok = \tan \phi.$$

In the triangle LPS

$$\cot PS \sin LP = \cos LP \cos LPS + \sin LPS \cot LPS,$$

or

$$\cot p \cos P = -\sin P \cos (\alpha - A) + \sin (\alpha - A) \cdot \frac{1}{\xi}.$$

Thus

$$\xi = \frac{\sin (\alpha - A)}{\cot p \cos P + \sin P \cos (\alpha - A)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Let

$$\tan p \cos (\alpha - A) = \tan q \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Then

$$\xi = \frac{\sin (\alpha - A)}{\cot p (\cos P + \sin P \tan q)}$$

$$= \frac{\sin (\alpha - A) \tan p \cos q}{\cos (P - q)}$$

$$= \frac{\tan (\alpha - A) \sin q}{\cos (P - q)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Again in $\Delta k$PS

$$\cot \mathrm{PS} \sin k\mathrm{P} = \cos k\mathrm{P} \cos k\mathrm{PS} + \sin k\mathrm{PS} \cot \mathrm{P}k\mathrm{S},$$

or

$$\cot p \sin (\mathrm{P}-\phi) = \cos (\mathrm{P}-\phi) \cos (\alpha-\mathrm{A}) + 0\,;$$

$$\therefore \tan (\mathrm{P}-\phi) = \cos (\alpha - \mathrm{A}) \tan p$$

$$= \tan q.$$

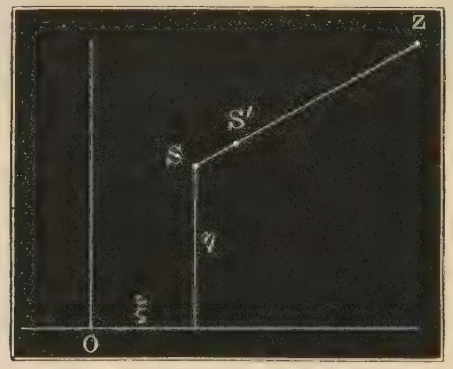
Thus

$$\eta = \tan \phi = \tan (\mathrm{P}-q) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Formulæ 2, 3, 4, give $\xi$ and $\eta$ in terms of $\alpha$, $p$, A, and P.

*Note II.*

If now S′ is a star on the plate, Z the projection of the zenith on the plane of the plate, and S be the true position of the star,




which is moved by refraction to S′ on the straight line SZ, then since SS′ is sensibly equal to its arc

$$\mathrm{SS}' = \beta_0 \tan \angle \mathrm{SCZ},$$

where C is the centre of the sphere.

Now if

(X, Y) be the co-ordinates of Z,
($\xi$, $\eta$) be the co-ordinates of S,

by a well-known theorem of solid geometry

$$\cos \mathrm{SCZ} = \frac{1 + \xi\mathrm{X} + \eta\mathrm{Y}}{\sqrt{1+\xi^2+\eta^2}\ \sqrt{1+\mathrm{X}^2+\mathrm{Y}^2}}.$$

Dr. Rambaut has shown that it is only necessary to retain the first powers of $\xi$ and $\eta$, and hence

$$\cos \mathrm{SCZ} = \frac{1}{\sqrt{1+\mathrm{X}^2+\mathrm{Y}^2}} \{1 + \xi\mathrm{X} + \eta\mathrm{Y}\}$$

$$= \cos \theta_0 \{1 + \xi\mathrm{X} + \eta\mathrm{Y}\},$$

where $\theta_0$ is the angle OCZ.

Thus

$$\tan \mathrm{SCZ} = \tan \theta_0 \{1 - \mathrm{cosec}^2 \theta_0 (\xi \mathrm{X} + \eta \mathrm{Y})\}$$
$$= \tan \theta_0 \left\{1 - \frac{\mathrm{X}^2 + \mathrm{Y}^2 + 1}{\mathrm{X}^2 + \mathrm{Y}^2} (\xi \mathrm{X} + \eta \mathrm{Y})\right\}.$$

Now the refraction resolved along $\xi$ is

$$d\xi = \mathrm{SS}' \frac{\mathrm{X} - \xi}{\sqrt{(\mathrm{X} - \xi)^2 + (\mathrm{Y} - \eta)^2}};$$

or

$$d\xi = \beta_0 \mathrm{X} \tan \theta_0 \left[1 - \frac{\mathrm{X}^2 + \mathrm{Y}^2 + 1}{\mathrm{X}^2 + \mathrm{Y}^2} (\mathrm{X}\xi + \mathrm{Y}\eta)\right] \left[1 - \frac{\xi}{\mathrm{X}}\right] \left[1 + \frac{\xi \mathrm{X} + \eta \mathrm{Y}}{\mathrm{X}^2 + \mathrm{Y}^2}\right]$$
$$= \beta_0 \mathrm{X} [1 - (\xi \mathrm{X} + \eta \mathrm{Y})] \left[1 - \frac{\xi}{\mathrm{X}}\right]$$
$$= \beta_0 [\mathrm{X} - \xi (1 + \mathrm{X}^2) - \eta \mathrm{XY}].$$

Now $\beta_0 \mathrm{X}$ is the refraction at the centre of the plate, and hence the *differential* refraction is

$$d\xi = -\beta_0 (1 + \mathrm{X}^2) \xi - \beta_0 \mathrm{XY} \cdot \eta; \quad \ldots \ldots \quad (5)$$

Similarly

$$d\eta = -\beta_0 \mathrm{XY} \xi - \beta_0 (1 + \mathrm{Y}^2) \eta. \quad \ldots \ldots \quad (6)$$

If the photograph is taken near the meridian X will be small.

The quantities X and Y are found by the formulæ of the preceding Note: putting $\alpha = \mathrm{S}$, the sidereal time of exposure of the photograph, and $p = \lambda$, the colatitude.
Thus

$$\tan q = \tan \lambda \cos (\mathrm{S} - \mathrm{A}),$$

and can be tabulated for any given place as a simple function of the hour angle S − A. Thus:

$$\mathrm{Y} = \tan (\mathrm{P} - q)$$

is known at once, and

$$\mathrm{X} = \frac{\tan (\mathrm{S} - \mathrm{A}) \sin q}{\cos (\mathrm{P} - q)}$$

is readily found.

$1 + \mathrm{X}^2$, X Y, and $1 + \mathrm{Y}^2$ can be formed quickly by Crelle's tables, three figures of decimals being amply sufficient. The magnitude of the quantities can be estimated by supposing X = 0, Y = 1, *i.e.* a photograph taken on the meridian at 45° zenith distance. Then

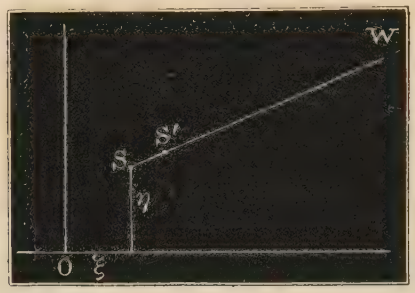
$$d\xi = -\beta_0 \xi;$$
$$d\eta = -2\beta_0 \eta.$$

Since $\xi$ and $\eta$ may vary from $+1^\circ \left(\frac{1}{57} \text{ in circ. measure}\right)$ to $-1^\circ \left(\text{or } -\frac{1}{57}\right)$, the corrections for refractions vary from $+\frac{1}{57}\beta_0$

to $-\frac{1}{57}\beta_0$ for $\xi$, and double this for $\eta$: *i.e.* (since $\beta_0 = 57''$, approximately) from $+1''$ to $-1''$, or $+2''$ to $-2''$ respectively.

*Note III.*

The investigation of the correction for aberration is very similar to that for refraction. If W be the projection of the




"Earth's Way" on the plate, the displacement SS′ is now proportional to sin SCW instead of tan SCZ.

Now

$$\sin \mathrm{SCW} = \sin\theta_0\,[1-\cos^2\theta_0\,(\xi X+\eta Y)].$$

Hence

$$d\xi = \gamma_0 \frac{X}{\sqrt{X^2+Y^2}} \sin\theta_0 \left[1-\frac{1}{X^2+Y^2}(\xi X+\eta Y)\right]\left[1-\frac{\xi}{X}\right]\left[1+\frac{\xi X+\eta Y}{X^2+Y^2}\right]$$

$$= \gamma_0 \frac{X\sin\theta_0}{\sqrt{X^2+Y^2}} \cdot \left[1-\frac{\xi}{X}\right]$$

$$= \gamma_0 \frac{X}{\sqrt{1+X^2+Y^2}} - \frac{\gamma_0\xi}{\sqrt{1+X^2+Y^2}}.$$

The first term is the aberration at the centre of the plate. Thus the differential aberration is

$$d\xi = -\frac{\gamma_0\xi}{\sqrt{1+X^2+Y^2}} \quad \ldots\ldots\ldots (7)$$

$$d\eta = -\frac{\gamma_0\eta}{\sqrt{1+X^2+Y^2}} \quad \ldots\ldots\ldots (8)$$

where $\gamma_0$ is the coefficient of aberration $= 20''{\cdot}4$ and (X, Y) is the projection of the "Earth's Way" on the plane of the plate.

*Note IV.*

*On the Relations between the Co-ordinates of the same object on two Different Plates.*

Let us first consider the relations between two sets of "Standard" co-ordinates, *i.e.* co-ordinates accurately perpendicular and

parallel to the meridian at the centre of the plate, expressed in circular measure. Let us call the two plates (1) and (2), and let the R.A.'s of their centres be $A_1$ and $A_2$, the N.P.D.'s being $P_1$ and $P_2$. Let $(x_1, y_1)$ be the co-ordinates of a point whose R.A. and N.P.D. are $(\alpha, p)$ on plate (1), and $(x_2, y_2)$ its co-ordinates on plate (2).

Then from Note I.

$$x_1 = \frac{\tan(\alpha - A_1)\sin q_1}{\cos(P_1 - q_1)}, \qquad y_1 = \tan(P_1 - q_1),$$

where

$$\tan q_1 = \tan p \cos(\alpha - A_1),$$

or more conveniently for our present purpose since

$$\tan(\alpha - A_1) = \sin(\alpha - A_1) \cdot \frac{\sin q_1}{\cos(\alpha - A_1)}$$
$$= \sin(\alpha - A_1)\tan p \cos q_1;$$

hence dividing both numerator and denominator of the expression for $x_1$ by $\cos q_1 \cos P_1$

$$x_1 = \frac{\tan p \sin(\alpha - A_1)\sec P_1}{1 + \tan p \tan P_1 \cos(\alpha - A_1)}$$

and

$$y_1 = \frac{\tan P_1 - \tan p \cos(\alpha - A_1)}{1 + \tan p \tan P_1 \cos(\alpha - A_1)}.$$

Thus

$$1 + y_1 \tan P_1 = \frac{\sec^2 P_1}{1 + \tan p \tan P_1 \cos(\alpha - A_1)}$$

and therefore

$$\tan p \sin(\alpha - A_1) = \frac{x_1 \sec P_1}{1 + y_1 \tan P_1};$$

$$\tan p \cos(\alpha - A_1) = \frac{\tan P_1 - y_1}{1 + y_1 \tan P_1}.$$

Thus we have, since

$$x_2 = \frac{\tan p \sin(\alpha - A_2)\sec P_2}{1 + \tan p \tan P_2 \cos(\alpha - A_2)} \quad \&c.,$$

writing

$$(\alpha - A_2) = (\alpha - A_1 + A_1 - A_2),$$

expanding the sine and cosine of the expression, and substituting the values of $\tan p \sin(\alpha - A_1)$ and $\tan p \cos(\alpha - A_1)$, from above,

$$x_2 = \frac{x_1 \sec P_1 \sec P_2 \cos \overline{A_1 - A_2} + (\tan P_1 - y_1)\sec P_2 \sin \overline{A_1 - A_2}}{1 + y_1 \tan P_1 + \tan P_2 (\tan P_1 - y_1)\cos \overline{A_1 - A_2} - x_1 \tan P_2 \sec P_1 \sin \overline{A_1 - A_2}}$$

and similarly

$$y_2 = \frac{\tan P_2 (1 + y_1 \tan P_1) - (\tan P_1 - y_1)\cos \overline{A_1 - A_2} + x_1 \sec P_1 \sin \overline{A_1 - A_2}}{\text{same denominator}}$$

Now let $(X_{12}, Y_{12})$ be the co-ordinates of the centre of plate (1) on plate (2). Then putting $x_1 = y_1 = 0$ in the above expressions we have

$$X_{12} = \frac{\tan P_1 \sec P_2 \sin \overline{A_1 - A_2}}{1 + \tan P_1 \tan P_2 \cos \overline{A_1 - A_2}};$$

$$Y_{12} = \frac{\tan P_2 - \tan P_1 \cos \overline{A_1 - A_2}}{1 + \tan P_1 \tan P_2 \cos \overline{A_1 - A_2}}.$$

Returning now to the expressions for $x_2$ and $y_2$, consider first the common denominator. Dividing throughout by the constant term $1 + \tan P_1 \tan P_2 \cos \overline{A_1 - A_2}$, which we may call D, the constant term becomes unity; the coefficient of $x_1$ becomes

$$(-\tan P_2 \sec P_1 \sin \overline{A_1 - A_2})/D$$

(which by comparison with the expression just obtained for $X_{12}$ we see to be $X_{21}$), and the coefficient of $y_1$ becomes

$$(\tan P_1 - \tan P_2 \cos \overline{A_1 - A_2})/D,$$

which is thus equal to $Y_{21}$.

Hence the denominator becomes

$$1 + x_1 X_{21} + y_1 Y_{21}.$$

In the numerator of the expression for $x_2$ the constant term is, of course, $X_{12}$.

The coefficients of $x_1$ and $y_1$ in the numerators of the expressions for $x_2$ and $y_2$ can be simplified by the use of the quantities $X_{12}$ $Y_{12}$ or $X_{21}$ $Y_{21}$. The expressions for these quantities in terms of $P_1$, $P_2$, and $\overline{A_1 - A_2}$ give four equations from which $P_1$, $P_2$, and $\overline{A_1 - A_2}$ can be eliminated, leaving one relation between the four quantities $X_{12}$, $Y_{12}$, $X_{21}$, $Y_{21}$. Without performing the elimination directly it is easily seen that this relation is

$$X_{12}^2 + Y_{12}^2 = X_{21}^2 + Y_{21}^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

each side of the equation being the square of the projection of the arc joining the two centres on the tangent planes at the extremities of that arc.

Further

$$X_{12} \sin P_2 + X_{21} \sin P_1 = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

and

$$\begin{aligned} &D(Y_{12} \sin P_2 \cos P_2 - Y_{21} \sin P_1 \cos P_1) \\ &= (\sin^2 P_2 - \sin^2 P_1) + \sin P_1 \sin P_2 \cos \overline{A_1 - A_2} \left( \frac{\cos P_1}{\cos P_2} - \frac{\cos P_2}{\cos P_1} \right) \\ &= (\sin^2 P_2 - \sin^2 P_1) D. \end{aligned}$$

Thus

$$Y_{12}\sin 2P_2 - Y_{21}\sin 2P_1 = \cos 2P_1 - \cos 2P_2 \quad . \quad . \quad . \quad . \quad (11)$$

These three relations independent of $A_2 - A_1$ are obviously all that can be obtained from the above four equations.

Again, we have

$$\left.\begin{aligned} D = 1 + \tan P_1 \tan P_2 \cos(A_1 - A_2) &= \frac{\sec^2 P_2}{1 + Y_{12}\tan P_2} \\ \tan P_1 \tan P_2 \cos(A_1 - A_2) &= \frac{\tan P_2 (\tan P_2 - Y_{12})}{1 + Y_{12}\tan P_2} \\ \tan P_1 \tan P_2 \sin(A_1 - A_2) &= \frac{X_{12}\tan P_2 \sec P_1}{1 + Y_{12}\tan P_2} \end{aligned}\right\}.$$

Thus

Hence in the numerator of the expression for $x_2$ the coefficient of $x_1$ is

$$\begin{aligned} &(\sec P_1 \sec P_2 \cos(A_1 - A_2))/D \\ &= \frac{\tan P_2 (\tan P_2 - Y_{12})}{\sin P_1 \sin P_2 \sec^2 P_2} \\ &= (\tan P_2 - Y_{12}) \cos P_2 \operatorname{cosec} P_1 \quad . \quad . \quad . \quad . \quad . \quad (12) \end{aligned}$$

We can give this a more symmetrical form by the use of the relation

$$\cos 2P_1 - \cos 2P_2 = Y_{12}\sin 2P_2 - Y_{21}\sin 2P_1,$$

viz.

$$\begin{aligned} &\frac{\sin P_2 (Y_{12}\sin 2P_2 - Y_{21}\sin 2P_1) - Y_{12}\cos P_2 (\cos 2P_1 - \cos 2P_2)}{\sin P_1 (Y_{12}\sin 2P - Y_{21}\sin 2P_1)} \\ &= \frac{Y_{12}\cos(2P_2 - P_2) - Y_{12}\cos P_2 \cos 2P_1) - Y_{21}\sin P_2 \sin 2P_1}{\sin P_1 (Y_{12}\sin 2P_2 - Y_{21}\sin 2P_1)} \\ &= \frac{Y_{12}\cos P_2 \sin P_1 - Y_{21}\sin P_2 \cos P_1}{Y_{12}\cos P_2 \sin P_2 - Y_{21}\sin P_1 \cos P_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13) \end{aligned}$$

The coefficient of $y_1$ in the numerator of $x_2$ is

$$\begin{aligned} &(-\sec P_2 \sin(A_1 - A_2))D \\ &= -X_{12}\operatorname{cosec} P_1 \sec P_2 \cos^2 P_2 \\ &= -X_{12}\frac{\cos P_2}{\sin P_1} \text{ or } X_{21}\cot P_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14) \end{aligned}$$

The coefficient of $x_1$ in the numerator of $y_2$ is

$$\begin{aligned} &(\sec P_1 \sin(A_1 - A_2))D \\ &= X_{12}\cot P_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15) \end{aligned}$$

The coefficient of $y_1$ in the numerator of $y_2$ is

$$\begin{aligned} &\{\tan P_1 \tan P_2 + \cos(A_1 - A_2)\} \div D \\ &= \tan P_1 \tan P_2 \cos^2 P_2 (1 + Y_{12}\tan P_2) + \cot P_1 \cos^2 P_2 (\tan P_2 - Y_{12}) \\ &= \sin P_2 \cos P_2 (\tan P_1 + \cot P_1) + Y_{12}(\sin^2 P_2 \tan P_1 - \cos^2 P_2 \cot P_1) \\ &= \frac{\sin 2P_2}{\sin 2P_1} + \frac{1}{2}Y_{12}\{(\tan P_1 - \cot P_1) - \cos 2P_2 (\tan P_1 + \cot P_1)\} \\ &= \frac{\sin 2P_2}{\sin 2P_1} - Y_{12}\left\{\frac{\cos 2P_1 + \cos 2P_2}{\sin 2P_1}\right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16) \end{aligned}$$

and by means of the relation

$$\cos 2P_1 - \cos 2P_2 = Y_{12} \sin 2P_2 - Y_{21} \sin 2P_1$$

this becomes

$$\frac{Y_{12} \sin 2P_1 - Y_{21} \sin 2P_2}{Y_{12} \sin 2P_2 - Y_{21} \sin 2P_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

Collecting the results, we have

$$\left.\begin{aligned} &\text{Numerator of } x_2 \\ &= x_1 \cdot \frac{Y_{12} \cos P_2 \sin P_1 - Y_{21} \sin P_2 \cos P_1}{Y_{12} \cos P_2 \sin P_2 - Y_{21} \sin P_1 \cos P_1} + y_1 \cdot X_{21} \cot P_2 + X_{12}. \\ &\text{Numerator of } y_2 \\ &= x_1 X_{12} \cot P_1 + y_1 \cdot \frac{Y_{12} \cos P_1 \sin P_1 - Y_{21} \sin P_2 \cos P_2}{Y_{12} \cos P_2 \sin P_2 - Y_{21} \sin P_1 \cos P_1} + Y_{12}. \end{aligned}\right\} \quad . \quad . \quad (18)$$

$$\text{Common denominator} = 1 + x_1 X_{21} + y_1 Y_{21}.$$

The expressions for the coefficients of $x_1$ in $x_2$, and $y_1$ in $y_2$, are, however, inconvenient; for when

$$P_1 = P_2, \qquad Y_{12} = Y_{21},$$

and they assume the indeterminate form $\frac{0}{0}$.

Hence when $P_1$ is nearly equal to $P_2$ they are not adapted to accurate calculation. The unsymmetrical expressions

$$\frac{\sin P_2}{\sin P_1} - Y_{12} \frac{\cos P_2}{\sin P_1}$$

and

$$\frac{\sin 2P_2}{\sin 2P_1} - Y_{12} \left\{ \frac{\cos 2P_1 + \cos 2P_2}{\sin 2P_1} \right\}$$

are better adapted for this purpose.

The above expressions are all rigorous. When $P_1$ and $P_2$ are not too small the coefficients of $x_1$ and $y_1$ in the numerators of $x_2$ and $y_2$ respectively are unity, to the first order of small quantities; and we have

$$\Delta x_2 = x_1 + y_1 X_{21} \cot P_2 + X_{12}$$
$$\Delta y_2 = x_1 X_{12} \cot P_1 + y_1 + Y_{12},$$

where

$$\Delta = 1 + x_1 X_{21} + y_1 Y_{21},$$

and all the quantities are in circular measure.

Secondly, consider the relations between actually measured co-ordinates on actual plates. These will only approximately

fulfil the theoretical conditions, owing to errors introduced by refraction, aberration, centreing, orientation, and scale values. All these should be very small, however; and if the co-ordinates $(x_1\ y_1)$ are corrected by the above formulæ they should agree very nearly with $(x_2\ y_2)$—within a few seconds of arc, say 10″. Let their corrected values be called $\xi_2$ and $\eta_2$.

Then

$$x_2 = (1+a)\,\xi_2 + b\eta_2 + c$$
$$y_2 = d\xi_2 + (1+e)\,\eta_2 + f,$$

where $a\ b\ c\ d\ e\ f$ are very small quantities of the order $\frac{10''}{60'}$ or $\frac{1}{360}$, whose squares and products only introduce errors of the order

$$60' \times \left(\frac{1}{360}\right)^2 = 0''{\cdot}03,$$

and may therefore be neglected. Hence if we have a chain of plates each overlapping the next, and if we first correct the co-ordinates of one by the theoretical expressions which should make them agree with those of the next, the differences between the co-ordinates of a star $x_1 - x_2$, $y_1 - y_2$ will be linear functions of $x$ and $y$ with very small coefficients, say

$$x_1 - x_2 = a_{12}x_1 + b_{12}y_1 + c_{12}$$
$$y_1 - y_2 = d_{12}x_1 + e_{12}y_1 + f_{12},$$

and it is easily seen that

$$a_{1n} = a_{12} + a_{23} + \ldots + a_{\overline{n-1}\,.\,n},$$

and similarly for the other coefficients. Any system of plates which returns to the same plate thus gives us 6 equations between the experimentally determined coefficients of relation between each two.

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*Greenwich Mean Times of Superior and Inferior Geocentric Conjunctions of Jupiter's Satellite Callisto from* 1894 *January to* 1895 *February.*

(*Communicated by the Superintendent of the Nautical Almanac.*)

The following times of geocentric conjunction of *Callisto* are in continuation of those published in *Monthly Notices*, vol. lii. p. 597, and are communicated to the Society with the view of drawing the attention of observers to the desirability of securing determinations of the positions of this satellite during the period

in which no observations of eclipses, occultations, or transits are possible.

On account of the interest and importance attaching to the first eclipses of a series, the times of superior heliocentric conjunctions of *Callisto*, occurring in 1894 December, are also given below. Assuming the accuracy of the tables, the first eclipse occurs on 1895 January 17; but it is quite possible that, owing to error in the tabular latitudes, there may be an eclipse of the satellite at one or both of the preceding conjunctions. And observers ought to be on the watch, on both these occasions, some considerable time before and after the predicted time of conjunction. The times of the corresponding inferior heliocentric conjunctions are also given, so as to enable observers to look out for the possible appearance of the shadow of the satellite on the disc on these occasions.

At the inferior heliocentric conjunction of *Callisto* on 1895 January 8, the shadow of the satellite ought, according to the tables, to fall on the disc of *Jupiter*. This first transit of shadow of the series was accidentally omitted from the *Nautical Almanac* for 1895. The following are the tabular times of ingress and egress of the shadow:—

Ingress: 1895 January $8^d\ 16^h\ 55^m$.
Egress: 1895 January $8^d\ 17^h\ 18^m$.

Superior Geocentric Conjunctions.

| 1894. | d | h | m | 1894. | d | h | m |
|---|---|---|---|---|---|---|---|
| Jan. | 12 | 22 | 46·9 | Aug. | 2 | 21 | 30·3 |
| | 29 | 15 | 45·4 | | 19 | 17 | 30·1 |
| Feb. | 15 | 9 | 44·7 | Sept. | 5 | 12 | 57·2 |
| Mar. | 4 | 4 | 37·3 | | 22 | 7 | 42·2 |
| | 21 | 0 | 12·9 | Oct. | 9 | 1 | 35·7 |
| Apr. | 6 | 20 | 20·8 | | 25 | 18 | 30·2 |
| | 23 | 16 | 51·9 | Nov. | 11 | 10 | 22·6 |
| May | 10 | 13 | 39·3 | | 28 | 1 | 18·4 |
| | 27 | 10 | 34·3 | Dec. | 14 | 15 | 32·7 |
| June | 13 | 7 | 31·2 | | 31 | 5 | 33·9 |
| | 30 | 4 | 24·0 | 1895. Jan. | 16 | 19 | 52·1 |
| July | 17 | 1 | 5·6 | Feb. | 2 | 10 | 53·8 |

Inferior Geocentric Conjunctions.

| 1894. | d | h | m | 1894. | d | h | m |
|---|---|---|---|---|---|---|---|
| Jan. | 4 | 16 | 2·4 | July | 25 | 12 | 2·5 |
| | 21 | 8 | 26·4 | Aug. | 11 | 8 | 12·1 |
| Feb. | 7 | 1 | 52·9 | | 28 | 3 | 53·2 |
| | 23 | 20 | 17·0 | Sept. | 13 | 22 | 56·8 |
| Mar. | 12 | 15 | 28·7 | | 30 | 17 | 13·3 |
| | 29 | 11 | 18·0 | Oct. | 17 | 10 | 34·8 |
| Apr. | 15 | 7 | 35·6 | Nov. | 3 | 2 | 55·7 |
| May | 2 | 4 | 12·2 | | 19 | 18 | 17·0 |
| | 19 | 1 | 1·1 | Dec. | 6 | 8 | 49·7 |
| June | 4 | 21 | 54·7 | | 22 | 22 | 54·7 |
| | 21 | 18 | 46·9 | 1895. Jan. | 8 | 13 | 1·6 |
| July | 8 | 15 | 31·6 | | 25 | 3 | 49·2 |
| | | | | Feb. | 10 | 19 | 7·8 |

Superior Heliocentric Conjunctions.

| 1894. | d | h | m | 1894. | d | h | m |
|---|---|---|---|---|---|---|---|
| Dec. | 14 | 13 | 34·3 | Dec. | 31 | 7 | 43·2 |

Inferior Heliocentric Conjunctions.

| 1894. | d | h | m | 1895. | d | h | m |
|---|---|---|---|---|---|---|---|
| Dec. | 22 | 23 | 0·1 | Jan. | 8 | 17 | 6·3 |

*Nautical Almanac Office:*
1893 *November* 8.

## *Observed Conjunctions of Satellite IV. with Jupiter.*

By the Rev. A. Freeman, M.A.

| Date. | Observed ☌. | Predicted ☌. | P−O. | Power. |
|---|---|---|---|---|
| 1892. | h m | h m | m | |
| (1) Nov. 3 | 10 6·25 | 10 18·5 | 12·25 | 116 |
| 1893. | | | | |
| (2) Feb. 20 | 6 16·1 | 6 22·0 | 5·9 | 165 |
| (3) Aug. 24 | 13 27·75 | 13 37·9 | 10·15 | 80 |
| (4) Oct. 13 | 15 9·2 | 15 12·7 | 3·5 | 116 |
| (5) Oct. 30 | 8 9·5 (W) | 8 17·5 | 8·0 | 116 |

By a conjunction is meant a position of the satellite upon the least apparent diameter of the planet, produced beyond the disc. In one case, marked (W), the position observed was upon the tangent to ♃'s disc at the west end of his equator; in this case 2 hours 25 minutes is assumed to be the interval since conjunction with the polar axis. Usually an equatorial refractor with $6\frac{1}{2}$ inches aperture was employed, except on August 24, when a refractor of 3 inches aperture was used. The predictions refer to Dr. Downing's list of conjunctions in *Monthly Notices*, vol. lii. p. 597. The following distances are mere estimates. Having no clock-work I made no attempt to measure them with the micrometer. Observations on September 10, September 18, October 5, and November 7, 1893, were impeded by cloud:—

(1) From centre of IV. to north pole of ♃ was one-third of polar radius of ♃.
(2) The N. limb of IV. separated from south pole of ♃ by a diameter of IV.'s disc.
(3) The N. limb of IV. separated from south pole of ♃ by one-fourth of polar radius of ♃.
(4) Centre of IV. is south of south pole of ♃ by about one-third of polar radius of ♃.
(5) Centre of IV. is south of south pole of ♃ by about one-third of polar radius of ♃.

The following observations have been supplied to me by Mr. A. Stanley Williams, of West Brighton. They were all made by himself with the aid of his reflecting telescope, having an aperture of $6\frac{1}{2}$ inches. I number them consecutively to my own, with which they may fitly be compared: —

| Date. | Observed ☌. | Predicted ☌. | P−O. | Power. |
|---|---|---|---|---|
| 1893. | h m | h m | m | |
| (6) Nov. 7 | 11 38·2 | 11 42·2 | 4·0 | 230 |
| 1890. | | | | |
| (7) June 24 | 15 5·3 | 14 57·5 | Shadow | 150 |
| (8) Aug. 30 | 8 32·4 | 8 44·5 | 12·1 | 230 |

The observer's own remarks are :—

(6) Clearly past conjunction $4^m$ after.

(7) A good observation of mid-transit of Shadow of IV.

(8) Sat. IV. appeared as a tolerably round, very dark, almost black spot.

In the case of (7) and (8) the predicted times are inferred from the *Nautical Almanac* for 1890.

*Murston Rectory, Sittingbourne :*
1893 *November* 8.

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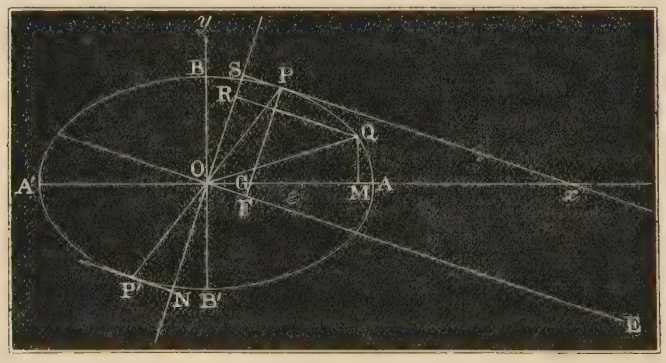
## *Method of Finding the Latitudes of Saturn's Belts.*

By the Rev. A. Freeman, M.A.

Numerous drawings of *Saturn* having been submitted to my inspection in the past two years, as drawn by several observers, it seems fit to show how they may be used for the purpose of determining the kronocentric latitudes of the edges of belts of the planet by measurement of the distance, taken along the central meridian, from the centre of the planet's disc to the point where the edge of any belt cuts that meridian. By this meridian is meant the line joining the apparent poles of the disc.




In the figure let the ellipse $ABA^1B^1$ be a section of *Saturn* by a plane passing through the Earth and the least axis of *Saturn*.

Let OE be the direction of the Earth, SP*x* a tangent parallel to OE, SON a straight line perpendicular to OE.

Then the apparent disc of *Saturn* is projected on the plane through SON perpendicular to OE, by straight lines in the direction of EO.

The apparent poles S, N are the projections of P and $P^1$.

PGF is normal to the elliptic section at P, Q is any point in this section which is projected in R upon SN, the central meridian of the disc of *Saturn*.

Let

$$\angle \text{POA} = \theta, \ \text{OP} = r,$$

then

$$\frac{\cos^2\theta}{a^2} + \frac{\sin^2\theta}{b^2} = \frac{1}{r^2}$$

if $a$ and $b$ are the semi-axes of *Saturn*.

Let $\epsilon$ = EOA be the elevation of the Earth north of *Saturn's* equator,

$$\text{PF} = r \cdot \sin(\theta + \epsilon) = \frac{b \cdot \sin(\theta + \epsilon)}{\sqrt{1 - e^2\cos^2\theta}},$$

where

$$b^2 = a^2(1 - e^2).$$

Again, let

$$\text{QOA} = \phi, \ \text{OQ} = r',$$

then

$$r' = \frac{b}{\sqrt{1 - e^2\cos^2\phi}},$$

and, if OM, QM be the co-ordinates of Q,

$$\text{OM} = \frac{b\cos\phi}{\sqrt{1 - e^2\cos^2\phi}}, \quad \text{QM} = \frac{b\sin\phi}{\sqrt{1 - e^2\cos^2\phi}}.$$

Now, QR being perpendicular to OS and parallel to EO,

$$\text{OR} = \text{OM} \cdot \sin\epsilon + \text{QM} \cdot \cos\epsilon = \frac{b\sin(\phi + \epsilon)}{\sqrt{1 - e^2\cos^2\phi}}.$$

To find the relation between $\theta$ and $\epsilon$, by consideration of the normal at P being perpendicular to OE, we have

$$\tan\epsilon = \frac{b^2\cos\theta}{a^2\sin\theta}, \text{ or } \cot\theta = \frac{\tan\epsilon}{1 - e^2}.$$

Hence it will be possible to substitute for $\theta$ in the expression for PF, so that we shall have

$$\text{PF} = a\sqrt{1 - \cos^2\epsilon},$$

after reductions.

Thus, finally,

$$\frac{\text{OR}}{\text{PF}} = \frac{b \cdot \sin(\phi + \epsilon)}{a\sqrt{1 - e^2\cos^2\phi} \cdot \sqrt{1 - e^2\cos^2\epsilon}} \quad \ldots\ldots \text{(A)}$$

Now, PF is the apparent polar semi-axis of *Saturn's* disc, and OR is the distance along the central meridian to a point on it which is the projection of Q, whose kronocentric latitude is $\phi$.

In 1893 the elevation of the Earth north of *Saturn's* equator ranged between 8°·802 on February 15 and 6°·093 on May 31; and it could be found from Marth's Ephemeris that the Earth's elevation was

| ° | d | h | |
|---|---|---|---|
| 8·5 on Feb. | 26 | 18·5 | |
| 7·5 on Apr. | 2 | 6·0 | . . . . . (B) |
| 6·5 on July | 5 | 21·0 | |

In the expression (A) $\epsilon$ is positive, south latitudes answer to positive values and north latitudes to negative values of $\phi$, OR being negative when R falls between O and N.

The following table, calculated by myself, gives the values of the expression (A) between south latitude 45° and north latitude 60° at intervals of 7°·5 and corresponding to the three assumed elevations (B). It will be easy by simple formulæ of interpolation to obtain from it values corresponding to the same latitudes, but to the different elevations 6°, 7°, 8°, 9°, and this will suffice for the measurement of all drawings of *Saturn* made in 1893.

We suppose

$$\frac{b}{a} = \frac{15''\cdot4}{17''\cdot3},$$

as given by Professor Oudemans (*Monthly Notices*, lii., 3), whence

$$e = 0\cdot455622$$

$$\log\left(\frac{b}{a}\right) = \bar{1}\cdot9494746, \qquad \log e = \bar{1}\cdot6586046.$$

The denominator was adapted to logarithms by assuming

$$e\cos\phi = \cos\phi_1, \text{ and } e\cos\epsilon = \cos\epsilon_1$$

*Table of the Values of the Expression* A.

| Lat. $\phi$ | $\epsilon = 8°\cdot5$ | $\epsilon = 7°\cdot5$ | $\epsilon = 6°\,5$ |
|---|---|---|---|
| ° | | | |
| S. 45 | +0·84671 | +0·83622 | +0 82530 |
| 37·5 | 0·76931 | 0·75675 | 0·74379 |
| 30 | 0 67555 | 0 66104 | 0·64626 |
| 22·5 | 0·56617 | 0·55003 | 0·53357 |
| 15 | 0·44274 | 0·42517 | 0·40741 |
| 7·5 | 0·30807 | 0·28950 | 0·27071 |
| 0 | 0·16557 | +0·14631 | +0·12696 |
| N. 7·5 | +0·01951 | 0 00000 | −0·01954 |
| 15 | −0·12569 | −0·14505 | 0·16431 |
| 22·5 | 0·26594 | 0·28471 | 0·30336 |
| 30 | 0·39773 | 0·41558 | 0·43323 |
| 37·5 | 0·51849 | 0·53510 | 0·55146 |
| 45 | 0·62653 | 0·64166 | 0·65648 |
| 52·5 | 0·72097 | 0·73435 | 0·74746 |
| 60 | −0·80145 | −0·81297 | −0·82418 |

I have extended this table to the elevations corresponding first of all to 7° and 8°, and then to the elevations, 6° and 9°, by formulæ of interpolation based on the method of *Boole's Finite Differences*, chap. iii. art. 4 of the third edition, assuming that if $u_0$, $u_1$, $u_2$, $u_3$, $u_4$, $u_5$, $u_6$ be the values of the expression (A) corresponding to a constant latitude $\phi$, but to elevations differing by half a degree,

$$8u_2 = 3u_1 + 6u_3 - u_5 \text{ and } 8u_4 = 3u_5 + 6u_3 - u_1,$$

and finally that, third differences assumed zero,

$$u_0 = u_3 + 3(u_1 - u_2), \text{ and } u_6 = u_3 - 3(u_4 - u_5).$$

The rest of the table now follows :—

| Lat. $\phi$ | $\epsilon=9°$ | $\epsilon=8°$ | $\epsilon=7°$ | $\epsilon=6°$ |
|---|---|---|---|---|
| S. 45° | +0·85179 | +0·84152 | +0·83081 | +0·81969 |
| 37·5 | 0·77553 | 0·76305 | 0·75309 | 0·72945 |
| 30 | 0·68273 | 0·66832 | 0·65368 | 0·63878 |
| 22·5 | 0·57512 | 0·55814 | 0·54184 | 0·52522 |
| 15 | 0·45145 | 0·43398 | 0·41631 | 0·39847 |
| 7·5 | 0·31728 | 0·29881 | 0·28013 | 0·26124 |
| 0 | 0·17520 | 0·15594 | 0·13665 | +0·11724 |
| N. 7·5 | +0·02925 | +0·00976 | −0·00975 | −0·02937 |
| 15 | −0·11769 | −0·13571 | −0·15456 | −0·17430 |
| 22·5 | 0·25631 | 0·27534 | 0·29405 | 0·31264 |
| 30 | 0·38893 | 0·40668 | 0·42418 | 0·44273 |
| 37·5 | 0·51008 | 0·52683 | 0·54331 | 0·55955 |
| 45 | 0·61511 | 0·63538 | 0·64911 | 0·66377 |
| 52·5 | 0·71419 | 0·72769 | 0·74094 | 0·75391 |
| 60 | −0·79557 | −0·80725 | −0·81861 | −0·82968 |

*Murston Rectory, Sittingbourne :*
1893 *November* 6.

*Observations of Phenomena of Jupiter's Satellites at Windsor, New South Wales, in the Year 1892.*
By John Tebbutt.

| Day of Obs. | Satellite. | Phenomenon. | Phase. | Aperture of Telescope. | Mag. Power. | Greenwich Mean Time of Observation. | Mean Time of *Nautical Almanac.* |
|---|---|---|---|---|---|---|---|
| 1892. | | | | | | h m s | h m s |
| Oct. 29 | I. | Tr. Ingr. | Ext. contact | 8-inch | 230 | 22 10 23 | |
| 29 | I. | ,, | Bisection | ,, | ,, | 22 12 23 | 22 10 |
| 29 | I. | ,, | Int. contact | ,, | ,, | 22 13 48 | |
| 30 | III. | ,, | Ext. contact | ,, | 300 | 0 7 19 | |
| 30 | III. | ,, | Bisection | ,, | ,, | 0 14 53 | 0 9 |
| 30 | III. | ,, | Int. contact | ,, | ,, | 0 21 47 | |
| 30 | I. | Tr. Egr. | Int. contact | ,, | ,, | 0 18 22 | |
| 30 | I. | ,, | Bisection | ,, | ,, | 0 20 7 | 0 22 |
| 30 | I. | ,, | Ext. contact | ,, | ,, | 0 22 17 | |
| 30 | III. | ,, | Int. contact | ,, | ,, | 1 49 32 | 2 10 |
| 30 | II. | Ecl. R. | First seen | ,, | 140 | 1 58 13 | 1 56 5 |
| 30 | I. | ,, | First seen | ,, | 170 | 22 3 28 | 22 3 27 |
| Nov. 14 | II. | Tr. Ingr. | Ext. contact | ,, | ,, | 21 48 12 | |
| 14 | II. | ,, | Bisection | ,, | ,, | 21 50 22 | 21 54 |
| 14 | II. | ,, | Int. contact | ,, | ,, | 21 52 41 | |
| 14 | I. | Tr. Egr. | Int. contact | ,, | ,, | 22 14 28 | |
| 14 | I. | ,, | Bisection | ,, | ,, | 22 17 22 | 22 19 |
| 14 | I. | ,, | Ext. contact | ,, | ,, | 22 19 37 | |
| 16 | III. | Occ. R. | Bisection | ,, | ,, | 22 25 9 | 22 35 |
| 16 | III. | ,, | Last contact | ,, | ,, | 22 27 24 | |

| Day of Obs. | Satellite. | Phenomenon. | Phase. | Aperture of Telescope. | Mag. Power. | Greenwich Mean Time of Observation. | Mean Time of *Nautical Almanac*. |
|---|---|---|---|---|---|---|---|
| 1892. | | | | | | h m s | h m s |
| Nov. 22 | I. | Ecl. R. | First seen | 8-inch | 170 | 22 19 7 | 22 19 15 |
| 22 | I. | ,, | Full brightness | ,, | ,, | 22 20 3 | |
| 23 | II. | ,, | First seen | ,, | ,, | 23 1 37 | 23 0 43 |
| 23 | II. | ,, | Full brightness | ,, | ,, | 23 4 11 | |
| 23 | III. | Occ. D. | First contact | ,, | ,, | 23 47 19 | |
| 23 | III. | ,, | Bisection | ,, | ,, | 23 52 23 | 23 52 |
| 23 | III. | ,, | Disappearance | ,, | ,, | 23 59 32 | |
| Dec. 7 | II. | ,, | First contact | ,, | 230 | 23 20 40 | |
| 7 | II. | ,, | Bisection | ,, | ,, | 23 22 55 | 23 24 |
| 7 | II. | ,, | Disappearance | ,, | ,, | 23 25 24 | |
| 23 | I. | Ecl. R. | First seen | $4\frac{1}{2}$-inch | 120 | 0 31 30 | 0 31 27 |
| 23 | I. | ,, | Full brightness | ,, | ,, | 0 34 0 | |

*Remarks.*

Oct. 29, 30.—Images steady and definition good; no trace of dark phase during transit of III. Eclipse of II. seen through thin cloud.

Nov. 14.—Excellent definition. II. seen as a bright spot on one of the belts 27 minutes after internal contact.

Nov. 16.—Excellent definition. Satellite small and oval, the major axis parallel to the limb of the primary.

Nov. 22, 23.—Excellent definition. At the critical moment a small filing cloud passed over II. Bisection of III. badly observed, owing to momentary bad definition.

Dec. 7.—Images tremulous and badly defined.

Dec. 23.—Sky beautifully clear; definition good, but images tremulous.

An occulting bar was not employed. The adopted longitude is $10^h\ 3^m\ 20^s{\cdot}51$ E. of Greenwich.

*Private Observatory, Windsor, N. S. Wales:*
1893 *September* 24.

*Observations of the Comet Rordame-Quénisset* (*b* 1893), *made at the Liverpool Observatory.* By W. E. Plummer.

The following observations were made with the Liverpool refractor of 8 inches aperture, employing either a filar micrometer or the arrangement of cross-bars recommended by Colonel Tupman, and referred to in the *Monthly Notices*, April 1893, p. 380. The references to each micrometer are the same as those mentioned in that place. With the filar micrometer the power used is 100, and with the 'reticule' either 40 or 62. The observations have been corrected for refraction in the manner suggested by the late Professor Challis. No correction has been applied for parallax. The horizontal equatorial parallax of the sun has been assumed 8″·848.

| 1893 | Greenwich Mean Solar Time of Observation. d | h | m | s | ☄−★ R.A. m | s | No. of Comparisons. | Apparent R.A. of ☄. h | m | s | ★−☄ Declination. ′ | ″ | No. of Comparisons. | Apparent Declination of ☄. ° | ′ | ″ | Log Factor of Parallax (α). | Log Factor of Parallax (δ). | Star of Comparison. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| July | 14 | 10 | 6 | 30 | +4 | 26·91 | 10 | 10 | 12 | 52·83 | + 7 | 41·5 | 5 | +38 | 36 | 35 6 | 9·6325 | 0·8170 | *a* |
| | 14 | 10 | 14 | 10 | +4 | 32·82 | Ret. | 10 | 12 | 58·74 | + 6 | 55·3 | Ret. | 38 | 35 | 49·4 | 9·6275 | 0·8239 | *a* |
| | 15 | 10 | 21 | 15 | −0 | 59·93 | 7 | 10 | 29 | 50·49 | − 2 | 50 0 | 4 | 36 | 15 | 58·3 | 9·6178 | 0·8266 | *b* |
| | | | | | −2 | 56·52 | 7 | 10 | 29 | 50·37 | −18 | 28·4 | 4 | 36 | 15 | 55·8 | ... | ... | *c* |
| | 17 | 10 | 45 | 16 | −3 | 3·98 | Ret. | 10 | 55 | 44·67 | − 1 | 39·2 | Ret. | 31 | 59 | 13·7 | 9 5917 | 0 8431 | *d* |
| | | | | | +0 | 8·42 | ... | 10 | 55 | 44·60 | + 9 | 50·0 | ... | 31 | 59 | 15·3 | ... | ... | *e* |
| | 20 | 9 | 22 | 40 | −0 | 24·51 | 10 | 11 | 20 | 38·94 | − 5 | 1 8 | 4 | 26 | 54 | 0·9 | 9·5970 | 0·7880 | *f* |
| | 21 | 9 | 34 | 41 | +2 | 36·75 | 10 | 11 | 26 | 51·87 | − 5 | 10 7 | 5 | 25 | 27 | 4·2 | 9·5923 | 0 8017 | *g* |
| | | | | | +2 | 27·24 | 10 | 11 | 26 | 51·75 | − 1 | 23·3 | 5 | 25 | 27 | 5·9 | ... | ... | *h* |
| | 22 | 10 | 11 | 25 | −2 | 15 27 | Ret. | 11 | 32 | 20 35 | −11 | 26·8 | Ret. | 24 | 6 | 38·8 | 9·5839 | 0·8286 | *i* |
| | | | | | −2 | 20·72 | ... | 11 | 32 | 20·40 | − 4 | 4·1 | ... | 24 | 6 | 36·5 | ... | ... | *j* |
| | 24 | 9 | 37 | 16 | +1 | 58·00 | 3 | 11 | 40 | 53 63 | − 7 | 8·0 | 3 | 21 | 51 | 12·2 | 9 5146 | 0·8145 | *k* |
| | 27 | 9 | 50 | 18 | −4 | 41·89 | Ret. | 11 | 50 | 27·69 | + 9 | 13·3 | Ret. | 19 | 5 | 4·8 | 9·5221 | 0·8278 | *l* |
| Aug. | 3 | 9 | 26 | 0 | −2 | 47·57 | ... | 12 | 3 | 42·55 | + 3 | 1·8 | ... | 14 | 39 | 48·7 | 9·5327 | 0·8353 | *m* |
| | | | | | +0 | 44·56 | ... | 12 | 3 | 42·69 | + 0 | 38·3 | ... | 14 | 39 | 46·5 | ... | ... | *n* |
| | 5 | 9 | 27 | 42 | −1 | 27·26 | 10 | 12 | 6 | 12·48 | + 4 | 13·8 | 5 | 13 | 43 | 35·0 | 9·5342 | 0·8396 | *o* |
| | 7 | 9 | 23 | 29 | +2 | 40·54 | 10 | 12 | 8 | 21·90 | −10 | 28·7 | 5 | 12 | 53 | 30·5 | 9·5357 | 0·8414 | *p* |
| | | | | | −0 | 16·21 | ... | 12 | 8 | 21·47 | + 9 | 0·4 | ... | 12 | 53 | 32·2 | ... | ... | *q* |
| | 8 | 9 | 27 | 55 | +0 | 26·71 | Ret. | 12 | 9 | 20·40 | + 5 | 28·2 | Ret. | +12 | 30 | 34·6 | 9·5355 | 0 8443 | *r* |

*Mean Places of Stars of Comparison.*

| Star's Designation or Authority. | Mean R.A. 1893·0. | Corr. to Apparent Place. | Mean Declination, 1893·0. | Corr. to Apparent Place. | Letter of Reference. |
|---|---|---|---|---|---|
| | h m s | s | ° ′ ″ | ″ | |
| Paris Catalogue, No. 12530 ... ... ... | 10 8 25·36 | +0·56 | +38 28 47·2 | +6·9 | *a* |
| „ „ No. 12987 ... ... ... | 10 30 39·78 | +0 64 | 36 18 41·8 | +6·5 | *b* |
| Weisse Bessel, x., No. 609 ... ... ... | 10 32 46·24 | +0 65 | 36 34 17·7 | +6·5 | *c* |
| Leiden Zones, 170, No. 38 ... ... ... | 10 58 47·92 | +0·73 | 32 0 47·8 | +5·1 | *d* |
| „ „ 170, No. 34 ... ... ... | 10 55 35·45 | +0·73 | 31 49 20·1 | +5·2 | *e* |
| Weisse Bessel, xi., No. 347 ... ... ... | 11 21 2·67 | +0·78 | 26 58 59·2 | +3·5 | *f* |
| Paris Catalogue, No. 14042 ... ... ... | 11 24 14·34 | +0·78 | 25 32 11·8 | +3·1 | *g* |
| „ „ „ 14044 ... ... ... | 11 24 23·73 | +0·78 | 25 28 26·1 | +3·1 | *h* |
| „ „ „ 14245 ... ... ... | 11 34 34·83 | +0·79 | 24 18 3·0 | +2 6 | *i* |
| „ „ „ 14247 ... ... ... | 11 34 40·33 | +0·79 | 24 10 40·6 | +2·6 | *j* |
| Bonn Zones, vol. vi., +22°, No. 2396 ... | 11 38 54·83 | +0·80 | 21 58 18·4 | +1·8 | *k* |
| Weisse Bessel, xi., No. 1041 ... ... ... | 11 55 8·77 | +0·81 | 18 55 50·7 | +0·8 | *l* |
| „ „ xii., No. 92 ... ... ... | 12 6 29·24 | +0·78 | 14 36 47·5 | −0·6 | *m* |
| Bonn Zones, vol. vi., +14°, No. 2476... ... | 12 2 57·35 | +0·78 | 14 39 8·8 | −0·6 | *n* |
| „ „ „ +13°, No. 2507... ... | 12 7 38·97 | +0·77 | 13 39 22·2 | −1·0 | *o* |
| Sch. No. 4395 ... ... ... ... ... | 12 5 40 61 | +0·75 | 13 4 0·4 | −1·2 | *p* |
| „ No. 4415 ... ... ... ... ... | 12 8 36·92 | +0·76 | 12 44 33·1 | −1·3 | *q* |
| Weisse Bessel, xii., No. 95 ... ... ... | 12 8 52·93 | +0·76 | +12 25 7·8 | −1·4 | *r* |

*Notes.*

July 14.—The star place differs somewhat from that given for No. 2117, zone 38° of the Bonn Catalogue.
July 15.—The comet was seen some time before a star of comparison could be seen on the light summer sky.
July 17.—Clouds interfered: the observation was not satisfactory. The condensation observed was north of the centre of the figure.
July 27.—The moon was bright, but the comet was still easily visible.
All the August observations were difficult. A haze rose from the sea and rendered observations near the horizon doubtful..

From the observations of July 14, 20 and August 3 the following orbit was computed:

*Perihelion Passage, July* 7, 2764 *G.M.T.*

| | | | | |
|---|---|---|---|---|
| $\omega$ | 47 | 7 | 54·2 | M. Eq. 1893.0 |
| $\Omega$ | 337 | 20 | 41·0 | |
| $i$ | 159 | 57 | 35·2 | |
| log $q$ | 9·829016 | | | |

From these elements an ephemeris was computed for the end of October, and a careful watch kept upon the places where the comet might be expected to be visible, but without effect.

*Liverpool Observatory:*
1893 *November* 7.

## *Observations of Brooks' Comet (c 1893), made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the East, or Sheepshanks, equatorial, aperture 6·7 inches, by taking transits over two cross wires at right angles to one another, and each inclined 45° to the parallel of declination.

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

| Greenwich Mean Solar Time. 1893. | | | | | Observer. | ☄ − ★ R.A. | Log Factor of Parallax. | Corr. for Refraction. | ☄ − ★ N.P.D. | Log Factor of Parallax. | Corr. for Refraction. | No. of Comps. | Appt. R.A. of ☄. | Appt. N.P.D. of ☄. | Comp. Star. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | d | h | m | s | | m s | | s | ′ ″ | | ″ | | h m s | ° ′ ″ | |
| Oct. | 18 | 16 | 58 | 18 | A.C. | + 6 10·24 | 9·5766 | +0·04 | + 7 51·8 | 0·8151 | +0·4 | 1 | 12 24 1·63 | 75 55 4·2 | *a* |
| | 18 | 17 | 3 | 47 | ,, | − 2 54·02 | 9·5754 | +0·05 | + 9 26·5 | 0·8131 | +0·5 | 1 | 12 24 1·24 | 75 54 38·9 | *b* |
| | 18 | 17 | 3 | 47 | ,, | −15 32·07 | 9·5754 | −0·01 | − 0 58·2 | 0·8131 | 0·0 | 1 | 12 24 1·82 | 75 54 35·3 | *c* |
| | 18 | 17 | 3 | 47 | ,, | −16 4·20 | 9·5754 | −0·03 | − 5 29·0 | 0·8131 | −0·2 | 1 | 12 24 1·19 | 75 54 39·5 | *d* |
| | 22 | 16 | 35 | 7 | B. | − 4 10·97 | 9·5842 | +0·03 | + 3 54·7 | 0·8135 | +0·2 | 1 | ... | ... | *g* |
| | 22 | 16 | 55 | 47 | ,, | + 3 19·40 | 9·5801 | +0·02 | + 3 50 6 | 0·8038 | 0 0 | 2 | ... | ... | *f* |
| | 22 | 16 | 58 | 33 | ,, | + 0 19·15 | 9·5794 | +0·01 | + 2 6·6 | 0·8026 | 0·0 | 2 | ... | ... | *e* |
| | 22 | 17 | 8 | 29 | A.C. | + 3 20·82 | 9·5757 | +0 01 | + 3 13 6 | 0·7977 | 0·0 | 3 | ... | ... | *f* |
| | 25 | 17 | 12 | 4 | ,, | − 0 0 15 | 9·5760 | −0·02 | − 6 57·2 | 0·7838 | −0·2 | 5 | ... | ... | *h* |
| | 25 | 17 | 15 | 29 | ,, | − 2 43·83 | 9·5744 | +0·01 | + 4 40·3 | 0·7820 | +0·1 | 2 | 12 33 37·13 | 71 9 43·2 | *i* |
| | 25 | 17 | 15 | 29 | ,, | − 3 24·06 | 9·5744 | 0·00 | + 1 24·8 | 0·7820 | +0·1 | 2 | 12 33 37·06 | 71 9 47·5 | *k* |
| | 26 | 16 | 12 | 40 | B. | − 1 3·90 | 9·5917 | +0·05 | + 8 19·8 | 0·8121 | +0·4 | 3 | 12 35 0·97 | 70 28 43·8 | *l* |
| | 26 | 16 | 17 | 57 | ,, | − 0 2·08 | 9·5916 | −0·05 | − 9 20·4 | 0·8094 | −0·4 | 3 | 12 35 0·84 | 70 28 47·8 | *m* |
| | 30 | 16 | 28 | 34 | ,, | + 2 6·78 | 9·5976 | +0·02 | + 6 45·5 | 0·7874 | 0·0 | 3 | 12 41 13·48 | 67 31 49·5 | *n* |
| | 30 | 16 | 35 | 58 | ,, | − 1 21·65 | 9·5956 | −0·04 | −15 29·5 | 0·7824 | −0·1 | 3 | 12 41 13·07 | 67 31 27·8 | *o* |

*Notes.*

Oct. 30.—The Comet was fairly bright, and had a diffused nucleus. A distinct tail was seen, 15′ in length, pointing in north preceding direction. The initials A. C. and B. are those of Mr. Crommelin and Mr. Bryant respectively.

*Assumed Mean Places of the Comparison Stars.*

| | Star's Name. | Assumed R.A., 1893·0. | Assumed N.P.D., 1893·0. | Authority. |
|---|---|---|---|---|
| | | h m s | ° ′ ″ | |
| *a* | W.B. XII. 257 | 12 17 50·37 | 75 47 3·2 | Lalande and Weisse's Bessel. |
| *b* | B.D. + 14°, 2512 | 12 26 54·26 | 75 45 3·0 | Pulkova Catalogue, 1875. |
| *c* | W.B. XII. 632 | 12 39 32·99 | 75 55 24·5 | Yarnall's Washington Catalogue, 1860. |
| *d* | W.B. XII. 646 | 12 40 4·51 | 75 59 59·7 | Glasgow Catalogue, 1870. |
| *e* | B.D. + 17°, 2492 | 12 25 59·5 | 73 11·6 | Bonn Observations, vol. iii. |
| *f* | Anonymous | 12 28 (59) | 73 14 | Difference from Star *e*. |
| *g* | B.D. + 17°, 2509 | 12 33 30·2 | 73 11·5 | Bonn Observations, vol. iii. |
| *h* | B.D. + 18°, 2636 | 12 33 34·4 | 71 16·4 | " " " |
| *i* | W.B. (2) XII. 726 | 12 36 19·91 | 71 4 51·6 | Weisse's Bessel, vol. ii. |
| *k* | W.B. (2) XII. 740, 741 | 12 37 0·09 | 71 8 11·4 | " " " |
| *l* | W.B. (2) XII. 723 | 12 36 3·76 | 70 20 12·0 | Lalande and Weisse's Bessel, vol. ii. |
| *m* | B.D. + 19°, 2593 | 12 35 1·91 | 70 37 57·1 | Bonn Observations, vol. vi. |
| *n* | W.B. (2) XII. 774, 775 | 12 39 5·56 | 67 24 50·8 | Berlin Zones, 72, 87. |
| *o* | W.B. (2) XII. 831 | 12 42 33·66 | 67 46 44·3 | " " " " |

*Erratum in Monthly Notices, Vol. LIII. No. 5, p. 346.*

Star *i* was wrongly identified; it is W.B. (2) O, 44. 1893·0 R.A. $0^h\ 5^m\ 0^s{\cdot}55$. N.P.D. 57° 27′ 51″·7. Authorities. 2nd Armagh and Paris Catalogues. The place of the anonymous star *h* (deduced from star *i*) should be 1893·0. R.A. $0^h\ 4^m\ 26^s$. N.P.D. 57° 32′.

*Royal Observatory, Greenwich:*
1893 *November* 8.

*Errata in Mr. Stone's Paper, Monthly Notices*, vol. liii. pp. 495–499.

In the collection of the results, the terms

$$\frac{m^2ee'^2}{2} - \frac{179}{144}m^4e$$

have been accidentally read into coefficient (1) instead of (2); and these coefficients therefore require correction.

The coefficient (1) should read

$$\left[1 + \frac{e^2}{2} - \left(\frac{1}{6} - \frac{355}{384}e^2 + \frac{e'^2}{4}\right)m^2 + \frac{1905}{256}m^3e^2 + \frac{331}{288}m^4 + \frac{83}{16}m^5\right].$$

The coefficient (2) should read

$$\left[-e + \frac{3}{8}e^3 - \frac{5}{192}e^5 - \frac{5}{2}e\gamma^4 + \frac{5}{4}e^3\gamma^2 + \left(\frac{11}{12}e + \frac{181}{128}e^3 - \frac{19}{32}e\gamma^2 + \frac{11}{8}ee'^2\right)m^2 + \frac{405}{64}m^3e + \frac{70027}{2304}m^4e\right].$$

Coefficient (4). In some copies, at the end of first line, for $-2\gamma$ read $-2\gamma^2$.

Coefficient (78). The denominator 64 has fallen out in the press.

Coefficient (85). For $\left[-\frac{15}{8}mee'\right]$ read $\left[-\frac{15}{16}mee'\right]$.

Coefficient (104). For $\left[\frac{75}{32}mee'\right]$ read $\left[\frac{105}{32}mee'\right]$.

*Erratum in Monthly Notices*, vol. xlviii. p. 327.

$\beta$ *Columbæ*, Proper Motion in Declination, for $-0''.06$ read $+0''.43$.

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